Licking and Cedar Run TMDL Study

Second Public Meeting

October 23, 2003

Essential Steps in TMDL Process

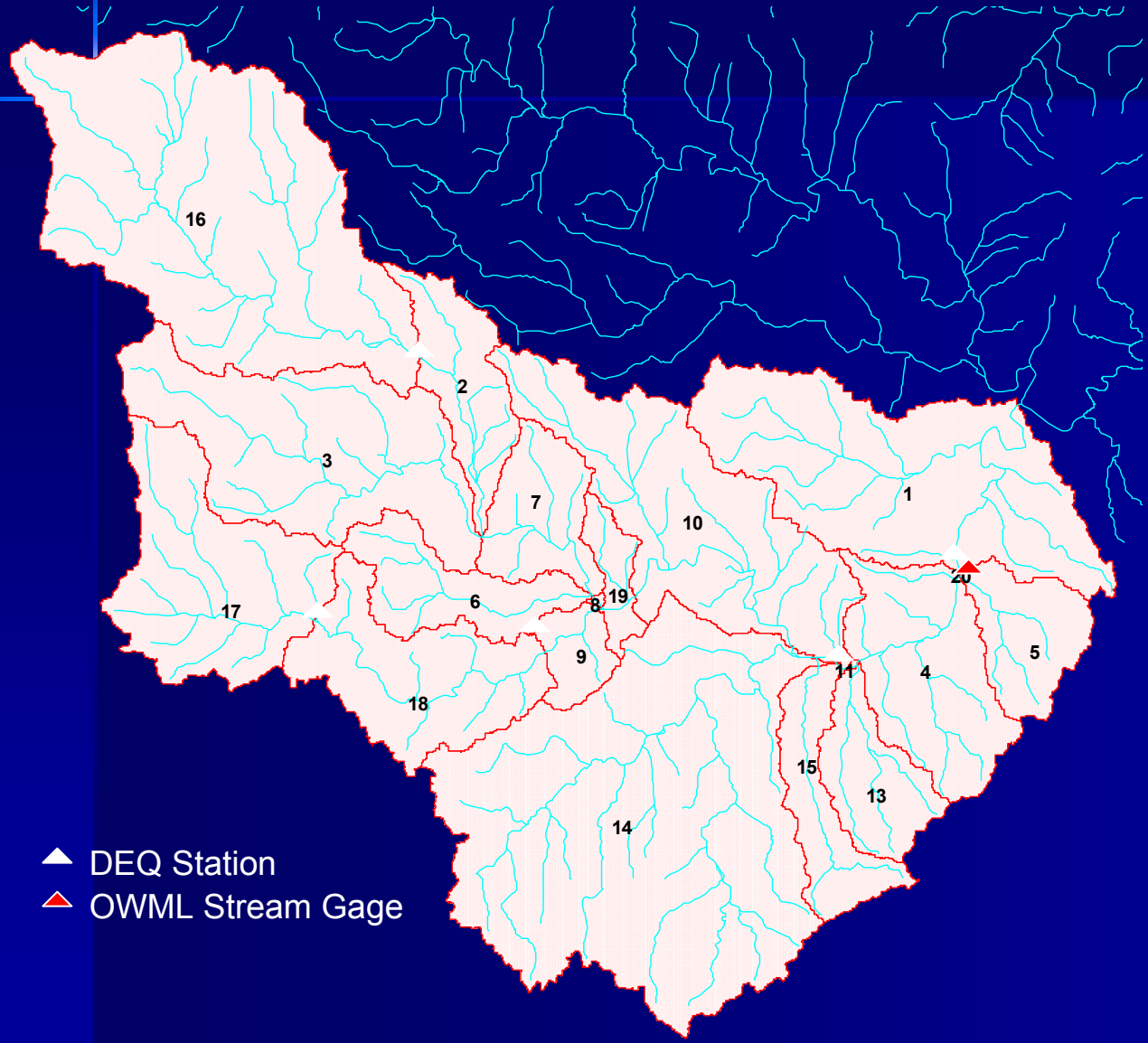
1. Source Assessment
   - Identify and quantify all existing sources of pollutant.
2. Computer Modeling
   - Develop model to explain and predict the response of the waterbody to different levels of pollutant loads.
3. Load Allocation
   - Determine level of pollutant load that allows the waterbody to meet water quality standards and allocate that load to sources.

Basin Setup

Modeling Simplified

- Pervious Land Block (PERLND)
  - Simulates all pervious land activities and computes runoff and pollutants loads.
- Impervious Land Block (IMPLND)
  - Simulates all impervious land activities and computes runoff and pollutant loads.
- Stream and River Block
  - Links the PERLND's and IMPLND's and routes streamflow in channels through a network of river reaches

Sub-Basin Delineation



Sub-basin	Acres
1	13,263
2	3,527
3	10,858
4	6,317
5	3,113
6	3,610
7	3,284
8	40
9	1,402
10	10,770
11	31
12	17
13	3,108
14	25,528
15	3,179
16	20,783
17	8,351
18	6,509
19	1,198
20	57

Land Use Inputs

- Pervious Land Block
  - Simulates all pervious land activities and computes runoff and pollutants loads.
    - Forest
    - Agricultural Lands
- Impervious Land Block
  - Simulates all impervious land activities and computes runoff and pollutant loads.
    - Developed Lands

Model Land Use Classes

Land Use	Perviousness (%)
Forest	100
Agricultural Tillage	100
Pasture	100
Low Density Residential	88
Medium Density Residential	62
Townhouse	35
Commercial	15
Industrial	28
Institutional	50
Misc. Urban Features	50

Land Use Distribution

Segment	Pervious Land (Acres)				Impervious Land (Acres)	
	Forest	Cropland	Pasture	Developed Land	Developed Land	Total
1	5,834	2,872	2,094	1,808	656	13,264
2	1,397	911	530	495	194	3,527
3	4,219	3,061	1,807	1,007	766	10,858
4	4,724	475	431	351	337	6,318
5	2,863	9	0	130	112	3,114
6	1,027	1,519	646	223	181	3,595
7	922	1,182	1,006	94	80	3,284
8	38	0	2	0	0	40
9	574	507	162	85	74	1,402
10	4,819	2,632	2,146	670	504	10,771
11	23	0	0	4	4	31
12	17	0	0	0	0	17
13	2,498	15	0	298	298	3,108
14	12,519	9,362	1,227	1,497	923	25,528
15	2,431	432	23	158	135	3,179
16	8,914	2,161	3,738	3,828	2,143	20,784
17	4,133	1,726	1,223	770	500	8,351
18	2,438	2,646	564	508	353	6,509
19	528	242	191	113	125	1,198
20	1	0	0	3	3	7
Total	59,918	29,752	15,789	12,042	7,385	124,885

Meteorology

- Model Inputs
  - Hourly Precipitation — Observed
  - Hourly Air Temperature — Observed
  - Hourly Wind — Observed
  - Hourly Dew Point Temperature — Observed
  - Hourly Solar Radiation — Calculated
  - Hourly Evaporation — Calculated
  - Hourly Evapotranspiration — Calculated

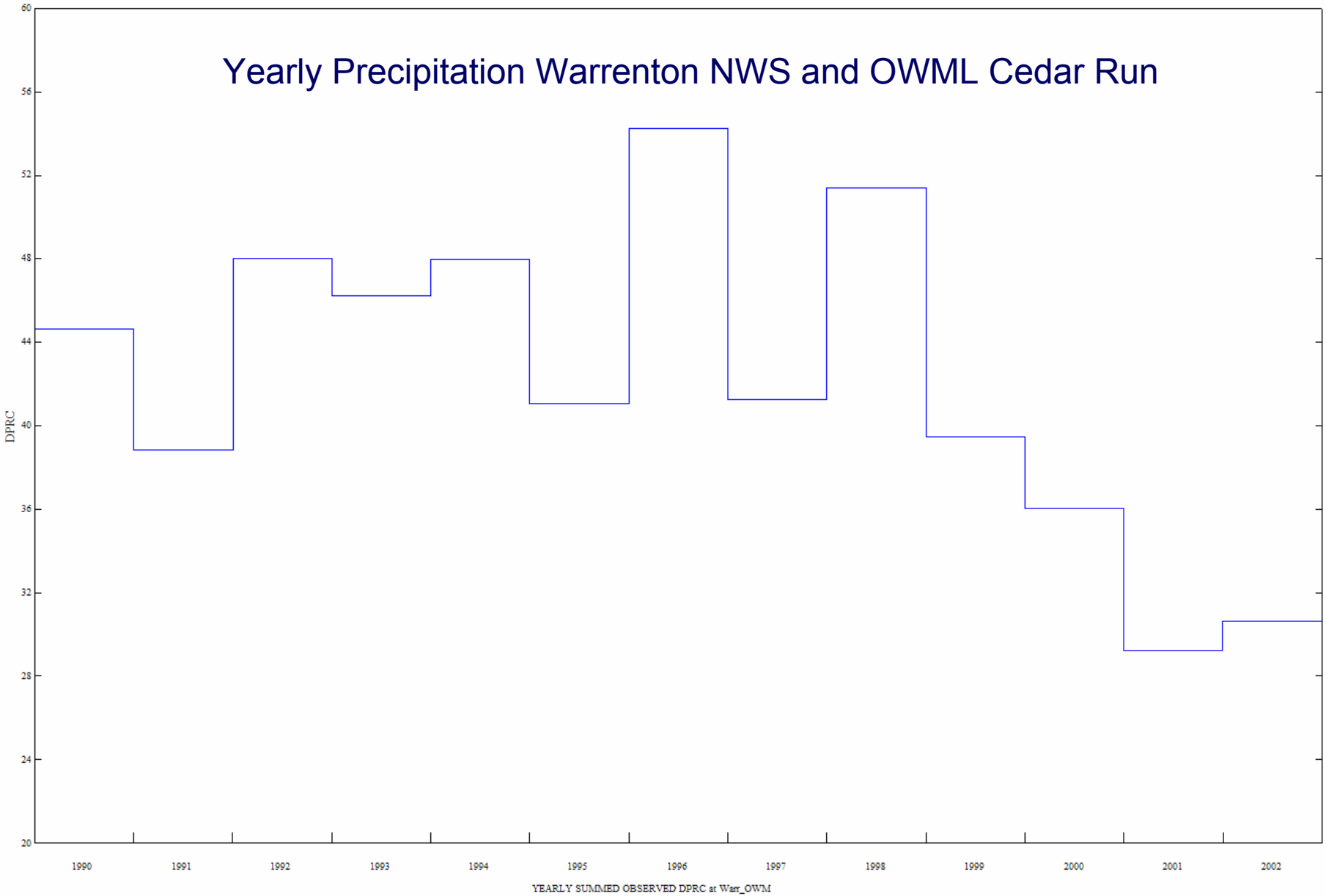
Meteorology (cont.)

- National Weather Service Stations
  - Warrenton
    - Daily Measurements Only
    - Effectively Closed After 2000
  - Dulles Airport
    - Predominantly Daily Measurements
    - Cloud Cover measurements ended 1996
  - National Airport
    - Hourly Measurements
    - Cloud Cover measurements ended 1996

Meteorology (cont.)

- Sterling Surface Irradiance Study
  - Direct solar radiation measurement study at Sterling NWS site
  - 1995 to Present
- Occoquan Monitoring Laboratory
  - Sub-hourly measurements in Manassas
  - Cedar Run Precipitation Gauge established 2001

Yearly Precipitation Warrenton NWS and OWML Cedar Run



Hydrology Calibration and Verification

Hydrology Calibration

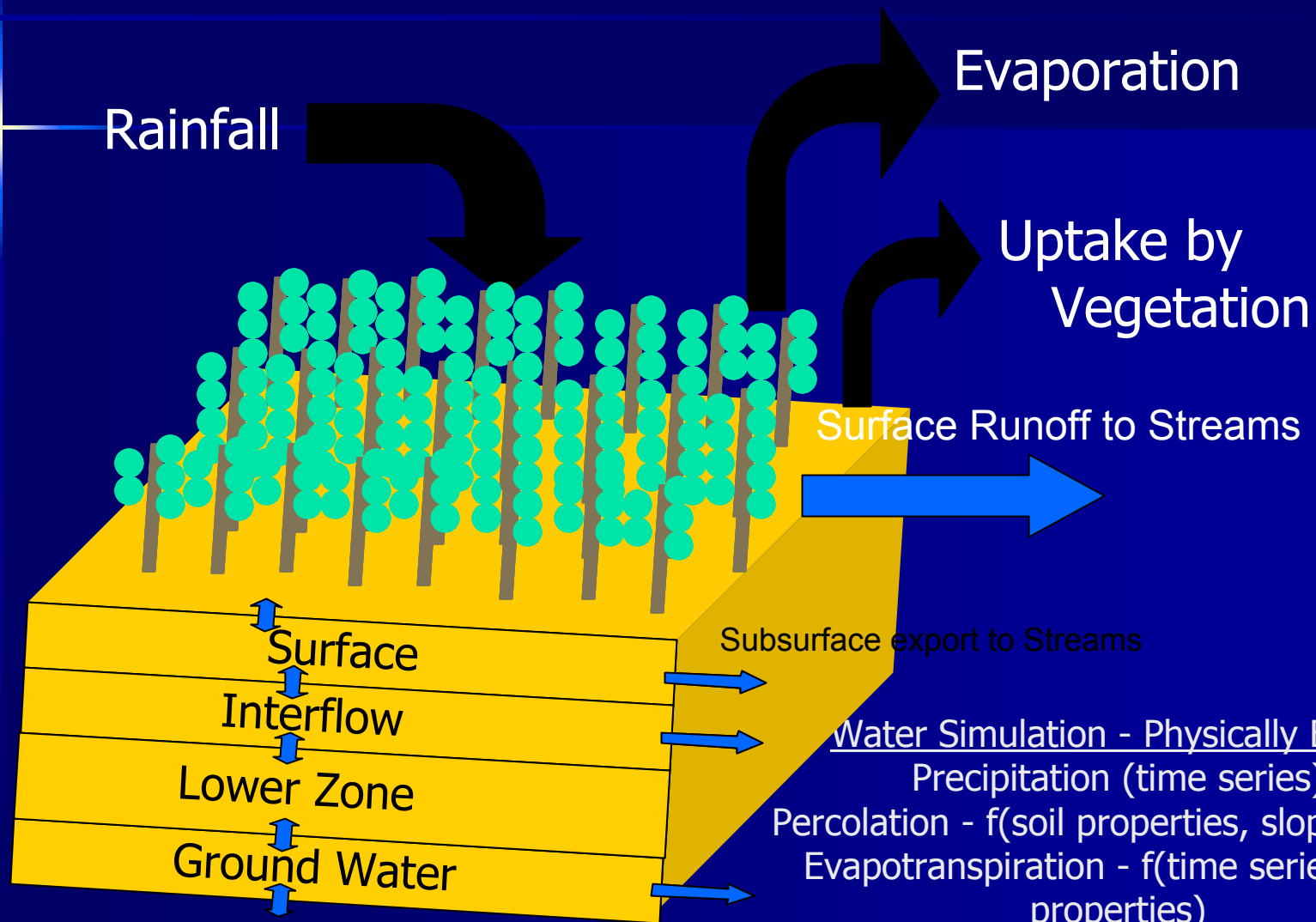
- Idea is to develop a simulated average daily flow similar to that of the observed flow at the OWML Cedar Run gage utilizing meteorological data and land use data

- Calibration Period: 1991-1995 (5 Years)
- Verification Period: 1997-2002 (6 Years)

Calibration "knobs"

Parameter	Definition	Units	Typical Range of Parameter Value	Initial Parameter Estimate	Calibrated Parameter Value
FOREST	Fractional forest cover		0.0 – 0.95	0	0
LZSN	Lower zone nominal soil moisture storage	in	2.0 – 15.0	3 – 12	6
INFILT	Index to infiltration capacity	in/hr-	0.001 – 0.50	0.01 – 0.3	.15
LSUR	Length of overland flow	ft	100 – 700	100 – 500	325 –350
SLSUR	Slope of overland flowplane		0.001 – 0.30	0.01 – 0. 3	0.15 – 0.2
KVARY	Groundwater recession variable	l/in	0.0 – 5.0	0	0
AGWRC	Base groundwater recession	l/day	0.85 – 0.999	0.05 - 0.99	0.99
PETMAX	Temp below which ET is reduced	degF	32.0 – 48.0	40	40
PETMIN	Temp below which ET is set to zero	degF	30.0 – 40.0	35	35
INFEXP	Exponent in infiltration equation		1.0 – 3.0	2	2
INFILD	Ratio of max/mean infiltration capacitites		1.0 – 3.0	2	2
DEEPFR	Fraction of GW inflow to deep recharge		0.0 – 0.50	0	0.8
BASETP	Fraction of remain ET from baseflow		0.0 – 0.20	0	0.1
AGWETP	Fraction of remain ET from active GW		0.0 – 0.20	0	0
CEPSC	Interception storage capacity	in	0.01 – 0.40	0.05 – 0.20	0.1
UZSN	Upper zonenominal soil moisture storage	in	0.05 – 2.0	0. 5 – 1.5	0.5
NSUR	Manning's (roughness)		0.10 – 0.50	0.1 – 0.5	0.2
INTFW	Interflow/surface runoff partition parameter		1.0 – 10.0	0.5 – 10	2
IRC	Interflow recession parameter	l/day	0.30 – 0.85	0.1 – 1	0.8
LZETP	Lower zone ET parameter		0.1 – 0.9	0.1 – 0.8	0.5
RETSC	Retention/interception storage capacity	in	0.0 – 1.0	0.001 – 1	0.01 – 0.05
KS	Weight factor for hydraulic routing		0.0 – 0.9	0.5	0.5

Land Simulation



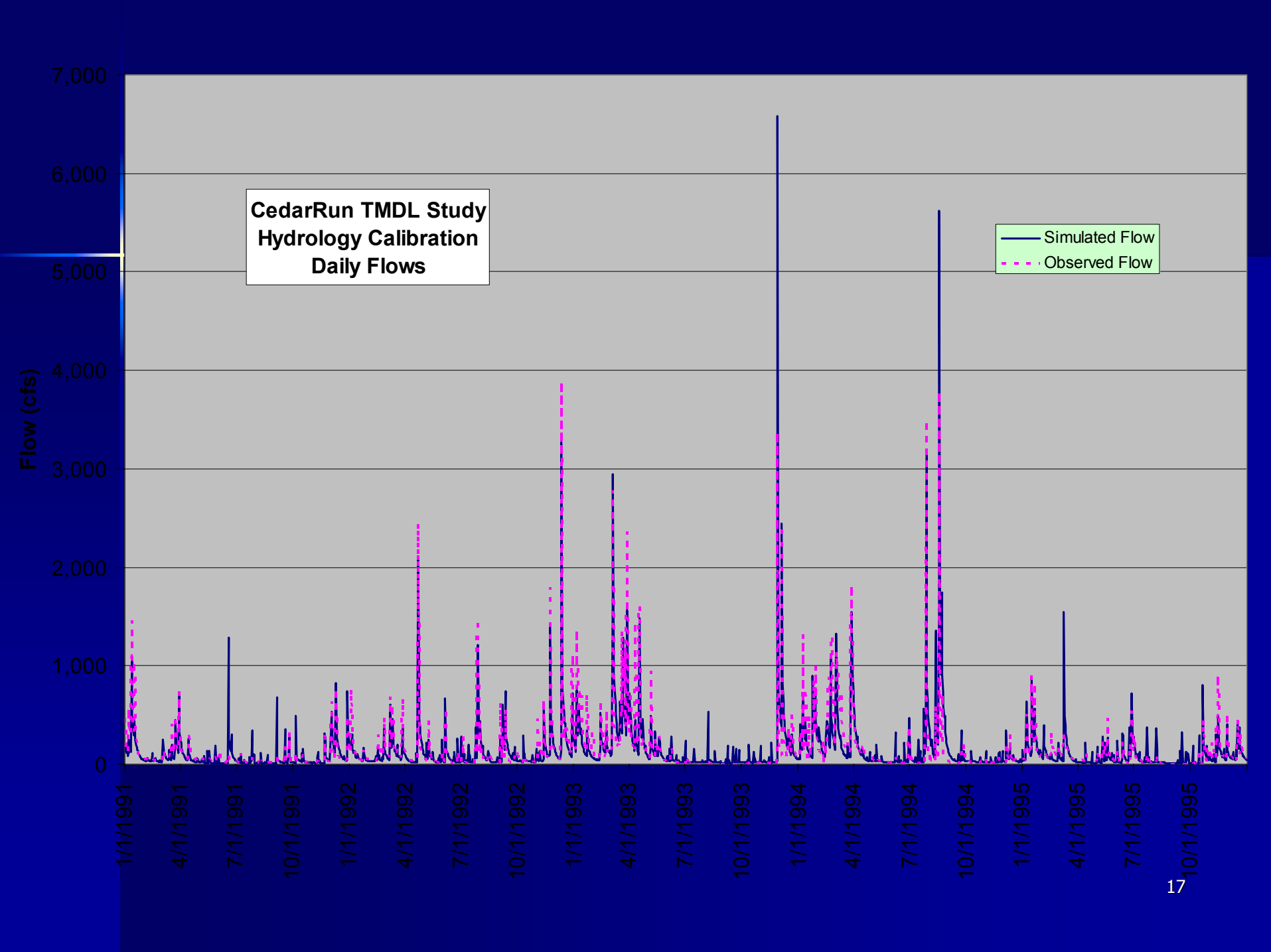
Water Simulation - Physically Based

Precipitation (time series)

Percolation - f(soil properties, slope, temp)

Evapotranspiration - f(time series, land properties)

Runoff - f(soil properties, slope, temp)


CedarRun TMDL Study
Hydrology Calibration
Daily Flows
Simulated Flow
Observed Flow
Flow (cfs)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1/1/1991
4/1/1991
7/1/1991
10/1/1991
1/1/1992
4/1/1992
7/1/1992
10/1/1992
1/1/1993
4/1/1993
7/1/1993
10/1/1993
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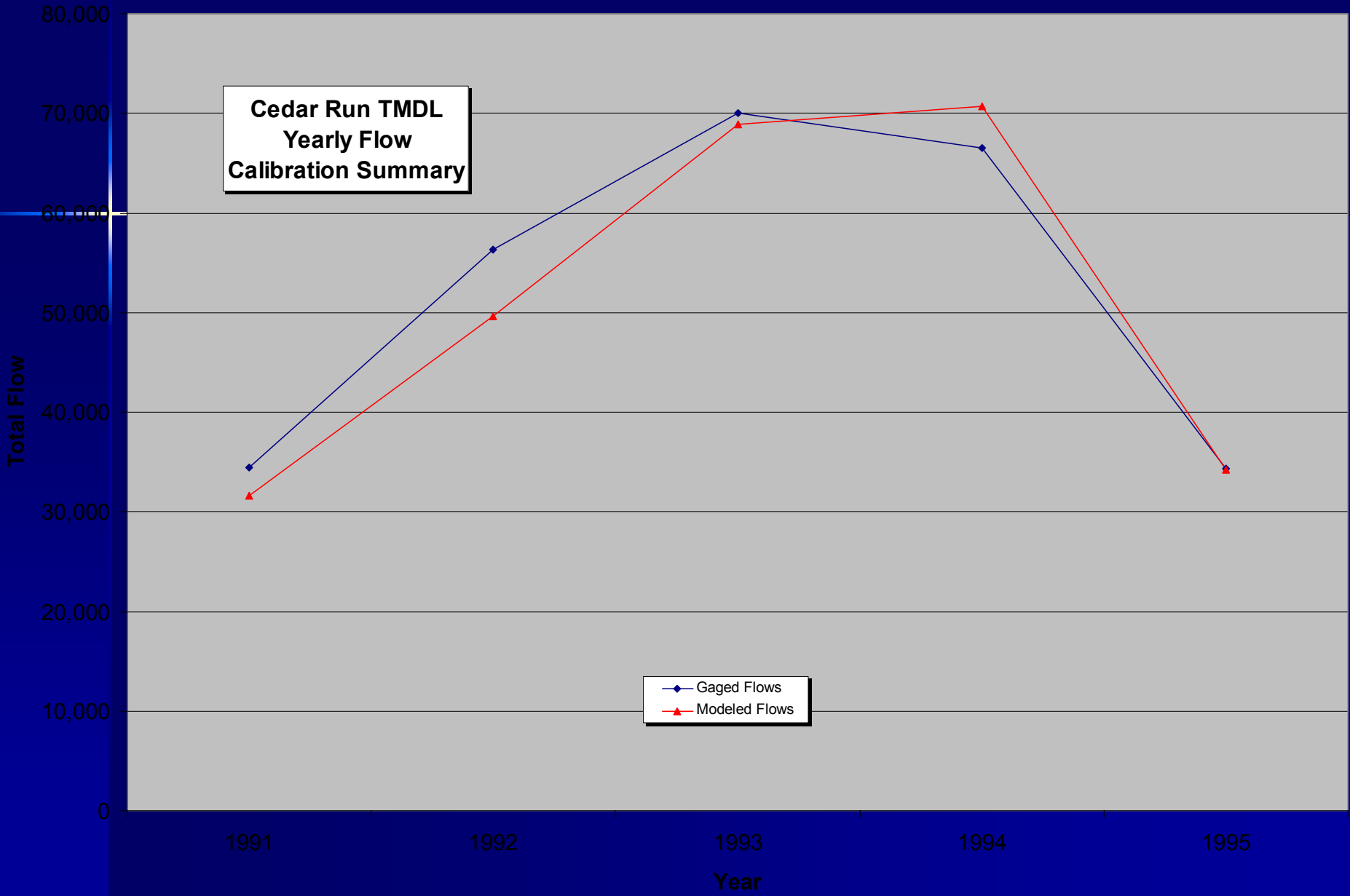
1/1/1995
4/1/1995
7/1/1995
10/1/1995


Cedar Run TMDL
Yearly Flow
Calibration Summary
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Total Flow
1991
1992
1993
1994
1995
Year
Gaged Flows
Modeled Flows

Calibration Summary

	Gaged Flows	Modeled Flows
1991	34,423	31,612= Total volume for 1991
1992	56,326	49,617= Total volume for 1992
1993	69,990	68,870= Total volume for 1993
1994	66,560	70,658= Total volume for 1994
1995	34,301	34,269= Total volume for 1995
	261,600	255,026= Total volume for entire simulation

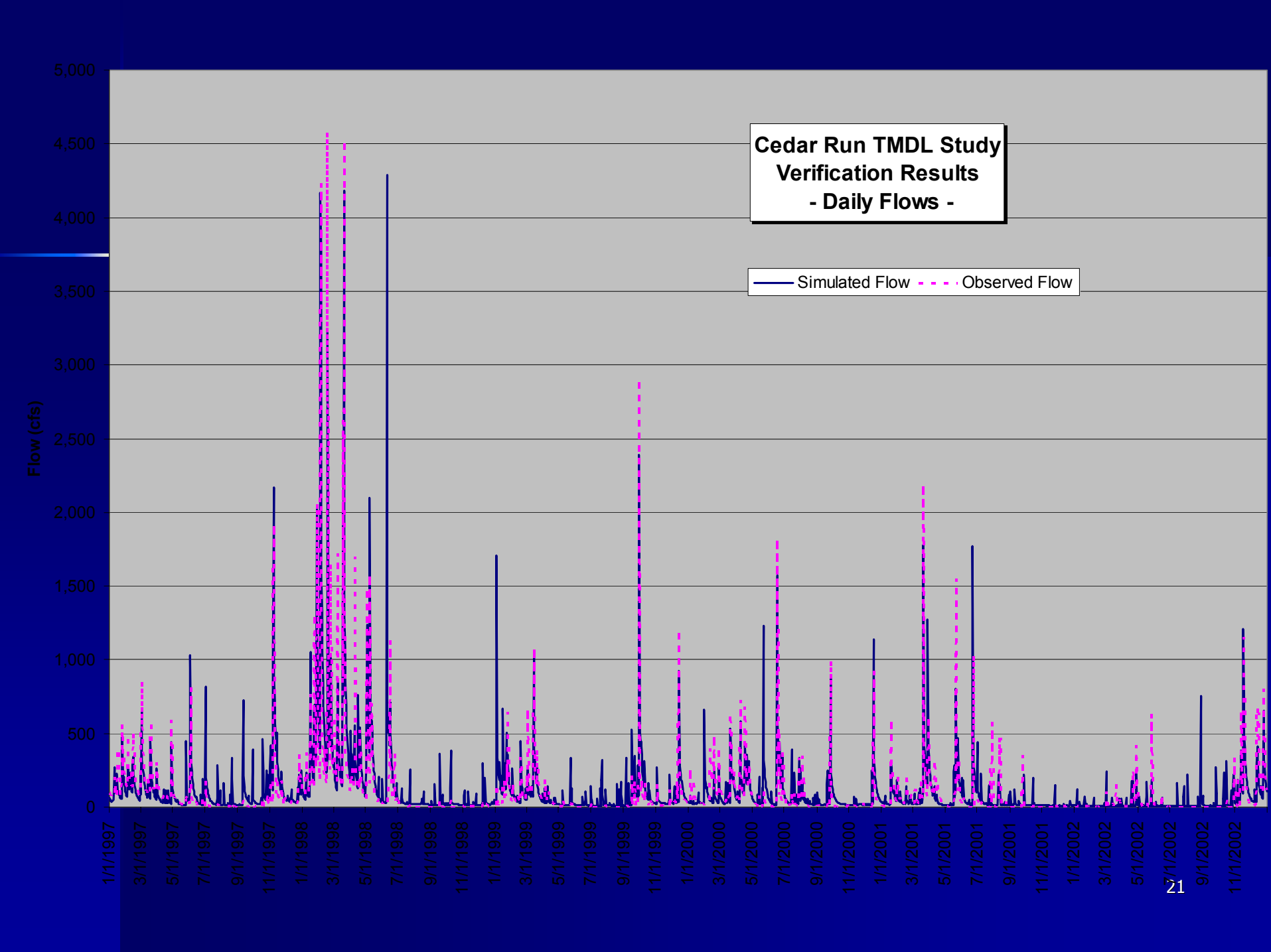
-8.2%= Volume balance error for 1991
-11.9%= Volume balance error for 1992
-1.6%= Volume balance error for 1993
6.2%= Volume balance error for 1994
-0.1%= Volume balance error for 1995
-2.5%= Volume balance error for entire simulation period

	Simulated	Observed
Total simulation Runoff	51.9 inches	55.9 inches
Total of highest 10% flows	27.5 inches	30.9 inches
Total of lowest 50% flows	4.2 inches	4.4 inches
Total storm volume	16.97 inches	16.16 inches
Average of storm peaks	1,297 cfs	1,223 cfs
Baseflow recession rate	0.96	0.90
Summer flow volume	11.55 inches	7.48 inches
Winter flow volume	16.22 inches	22.04 inches
Summer storm volume	6.25 inches	4.57 inches

	Current	Criteria
Error in total volume	-7.1	±10.0
Error in 50% lowest flows	-4.6	±10.0
Error in 10% highest flows	-11.2	±15.0
Error in storm peaks	6.1	±15.0
Seasonal volume error	80.9	±10.0
Summer storm volume error	31.8	±15.0

Model Verification

- Verification Period is used to "verify" calibration parameter settings over different time period.
- A slightly longer verification period (6 years) was chosen to verify the calibration
  - 1997 through 2002


Cedar Run TMDL Study
Verification Results
- Daily Flows -
Simulated Flow
Observed Flow
Flow (cfs)
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1/1/1997
3/1/1997
5/1/1997
7/1/1997
9/1/1997
11/1/1997
1/1/1998
3/1/1998
5/1/1998
7/1/1998
9/1/1998
11/1/1998
1/1/1999
3/1/1999
5/1/1999
7/1/1999
9/1/1999
11/1/1999
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9/1/2000
11/1/2000
1/1/2001
3/1/2001
5/1/2001
7/1/2001
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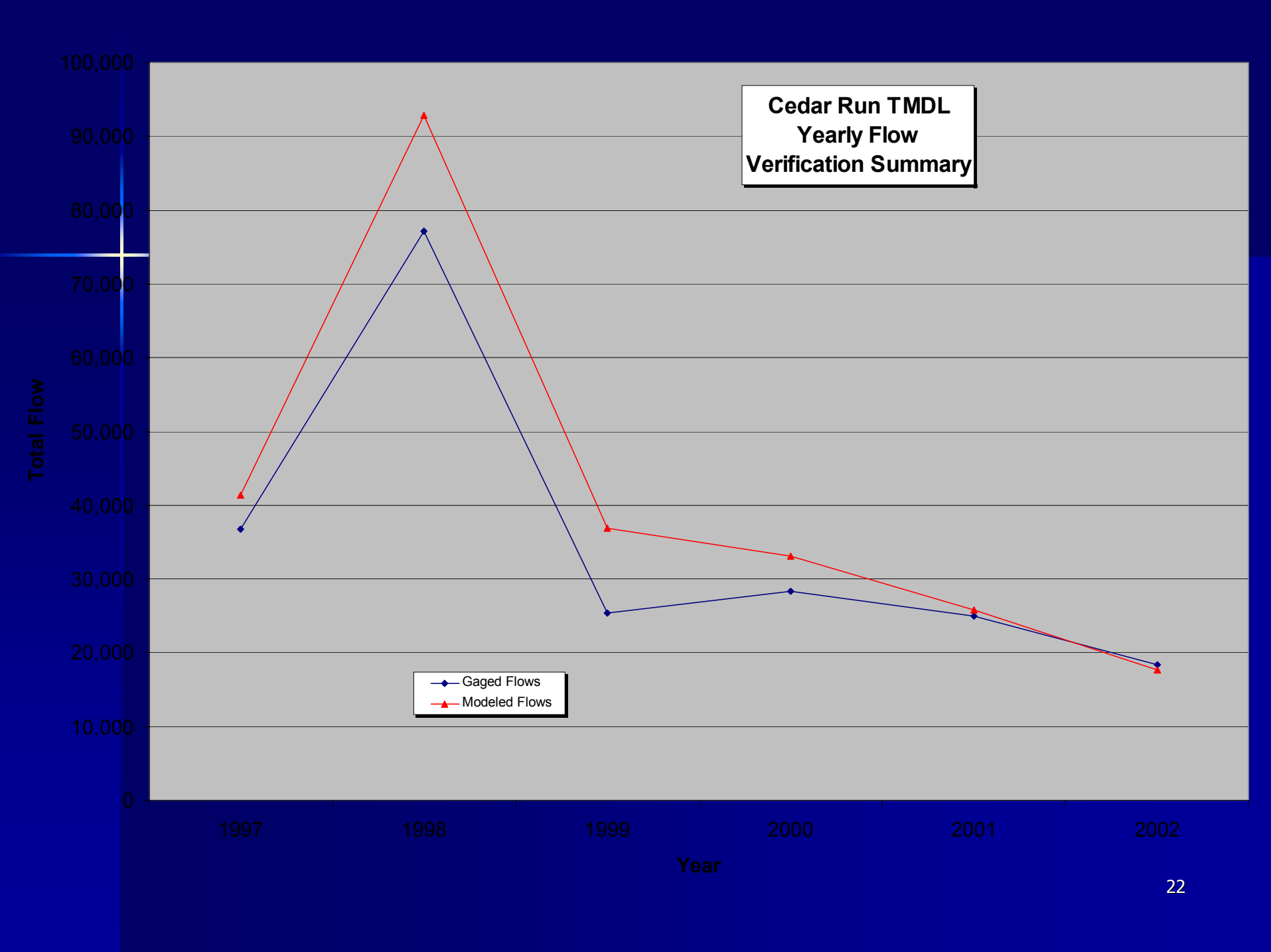
5/1/2002
7/1/2002
9/1/2002
11/1/2002


Cedar Run TMDL
Yearly Flow
Verification Summary
Total Flow
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
1997
1998
1999
2000
2001
2002
Year
Gaged Flows
Modeled Flows

Verification Summary

	Gaged Flows	Modeled Flows
1997	36,708	41,306= Total volume for 1997
1998	77,147	92,848= Total volume for 1998
1999	25,432	36,835= Total volume for 1999
2000	28,293	33,061= Total volume for 2000
2001	24,903	25,825= Total volume for 2001
2002	18,377	17,711= Total volume for 2002
	210,860	247,587= Total volume for entire simulation

12.5%= Volume balance error for 1997
20.4%= Volume balance error for 1998
44.8%= Volume balance error for 1998
16.9%= Volume balance error for 2000
3.7%= Volume balance error for 2001
-3.6%= Volume balance error for 2002

17.4%= Volume balance error for entire simulation period

Bacteria Source Assessments

Bacteria Source Assessments

- Determine human and animal populations by subwatershed
- Estimate bacteria produced per animal per day
- Calculate how much of the bacteria is deposited directly in streams and how much is deposited on the land surface

Sources of Bacteria

- Human Sources
  - Failing Septic Systems
  - Straight Pipes
  - Point Sources
    - Sewage Treatment Plants
      - POTW
      - Private Residences
  - Biosolids Applications

Sources of Bacteria (cont.)

- Agricultural and Domestic Sources
  - Beef Cattle
  - Dairy Cattle
  - Horses and Ponies
  - Sheep and Lambs
  - Hogs and Pigs
  - Poultry
  - Goats
  - Dogs and Cats

Sources of Bacteria (cont.)

- Wildlife Sources
  - Deer
  - Raccoons
  - Muskrats
  - Beavers
  - Turkeys
  - Geese
  - Ducks
  - -- Skunk
  - -- Possum

Point Sources

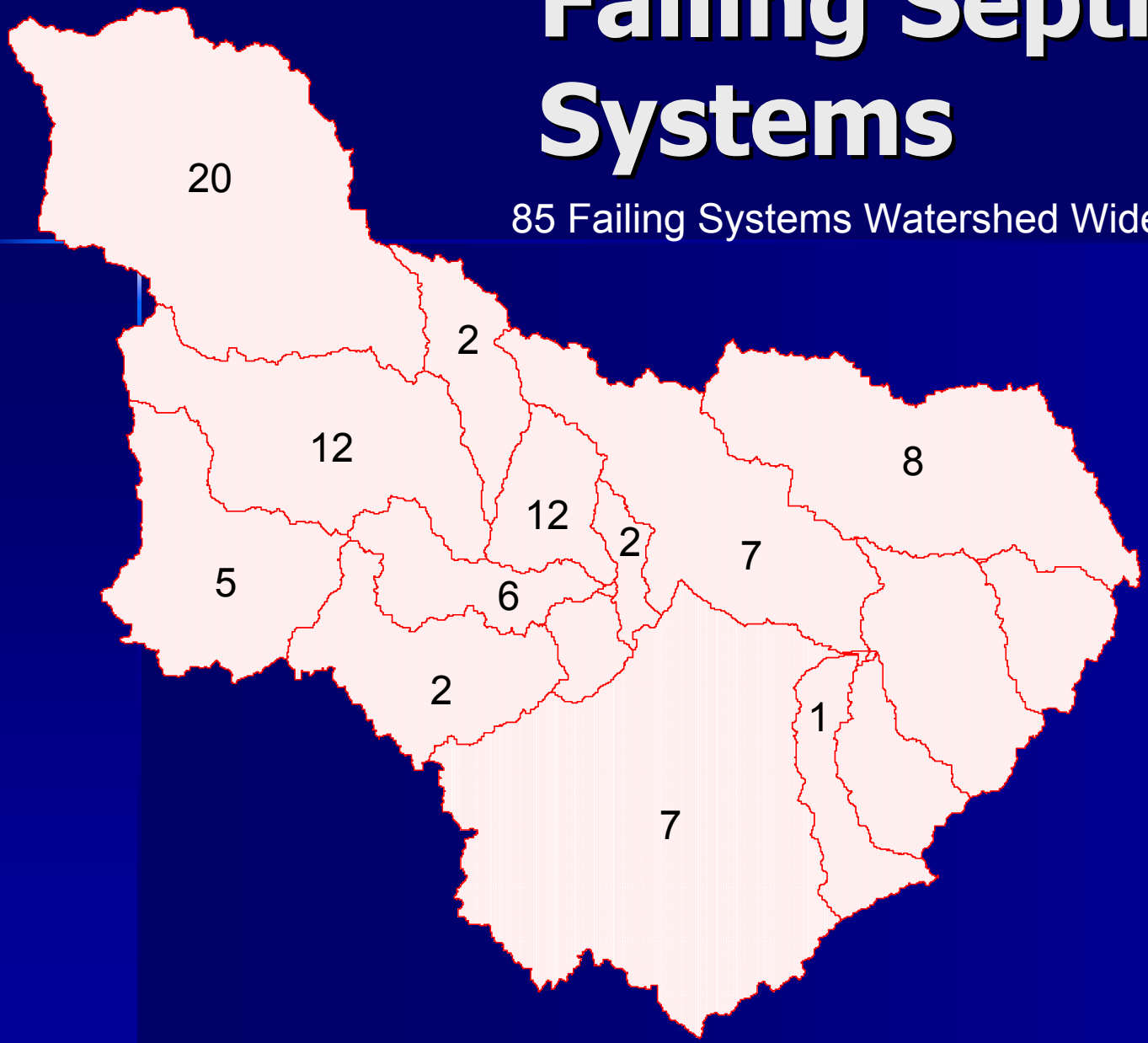
VPDES Permitted Point Sources

Facility	County	Permit No.	Discharge	Receiving Stream	Model Segment
Smith Midland Incorporated	Fauquier	VA0084298	0.0015 mgd	Licking Run	18
Smith Midland Incorporated	Fauquier	VA0084298	0.0015 mgd	Licking Run	18
US Marine Corps - Quantico	Prince William	VA0028371	0.04 mgd	Cedar Run	4
Residence	Prince William	VAG406075	Less than 1,000 gpd	Cedar Run	1
Residence	Prince William	VAG406089	Less than 1,000 gpd	Cedar Run	10
Residence	Prince William	VAG406090	Less than 1,000 gpd	Cedar Run	1
Residence	Prince William	VAG406091	Less than 1,000 gpd	Cedar Run	10
Residence	Prince William	VAG406108	Less than 1,000 gpd	Slate Run	1
Residence	Prince William	VAG406126	Less than 1,000 gpd	Slate Run	1
Residence	Fauquier	VAG406188	Less than 1,000 gpd	Mill Run	16
Residence	Fauquier	VAG406192	Less than 1,000 gpd	Mill Run	16
Residence	Prince William	VAG406210	Less than 1,000 gpd	Slate Run	1
Residence	Prince William	VAG406267	Less than 1,000 gpd	Cedar Run	10
CAFO	Fauquier	VAG130007	Less than 1,000 gpd	Licking Run	18
CAFO	Fauquier	VAG130008	Less than 1,000 gpd		6
CAFO	Fauquier	VAG130023	Less than 1,000 gpd		14

Septic Systems

Failing Septic Systems

85 Failing Systems Watershed Wide



Sub-basin	Housing Units	Fail Septic
1	846	8
2	224	2
3	1168	12
4	47	0
5	7	0
6	127	6
7	118	12
8	1	0
9	48	0
10	342	7
11	0	0
12	0	0
13	18	0
14	656	7
15	64	1
16	3983	20
17	514	5
18	218	2
19	42	2
20	0	0

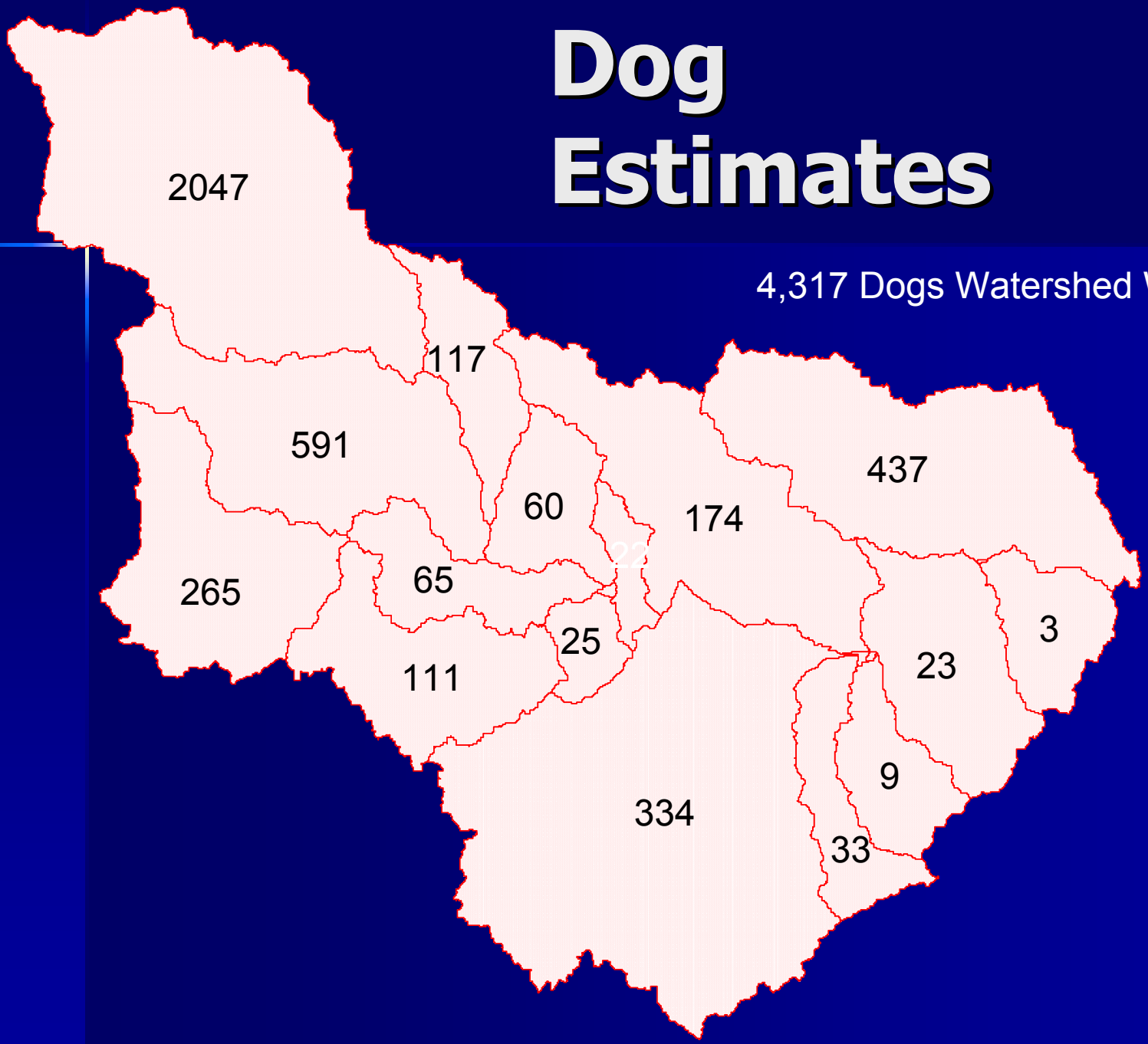
Pet Estimates

- Developed on estimates from:
  - 2000 US Census Block Group data
  - 0.534 dogs per household[1]
  - 0.598 cats per household[1]
  - TAC Recommendation 1.1 dogs Rural Sub-basins
  - Avg. Fecal Coliform Production:
    - 4.50e+09 bacteria/capita/day

1. American Veterinary Medical Association, 2002

Dog Estimates

4,317 Dogs Watershed Wide



Lifestock Estimates

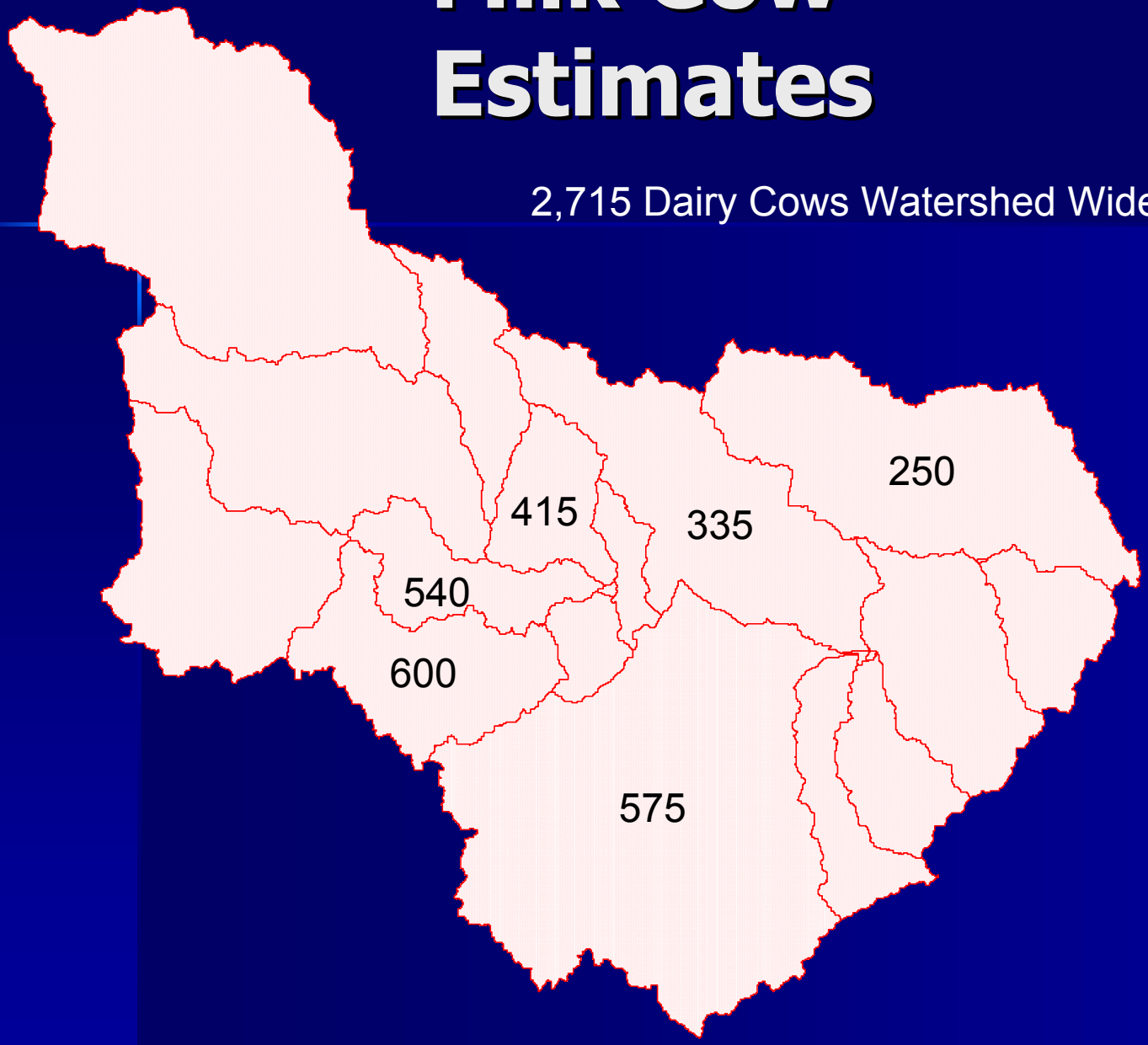
- Based on 1997 Agricultural Census
- Applied equivalent percentage to Agricultural Census to develop initial livestock estimates for Cedar Run study area
- Adjusted sub-basin numbers upon consultation with TAC members

Livestock Estimates

	1997 County Wide Census	Cedar Run Estimates
Milk Cows	29,504	2,715
Beef Cows	15,540	1,930
Steers and Heifers	13,925	3,361
Horses and Ponies	4,195	1,066
Sheeps and Lambs	1,650	283
Poultry	1,588	283
Hogs and Pigs	461	204
Goats	176	84
Mules, burros, and donkeys	70	13

Milk Cow Estimates

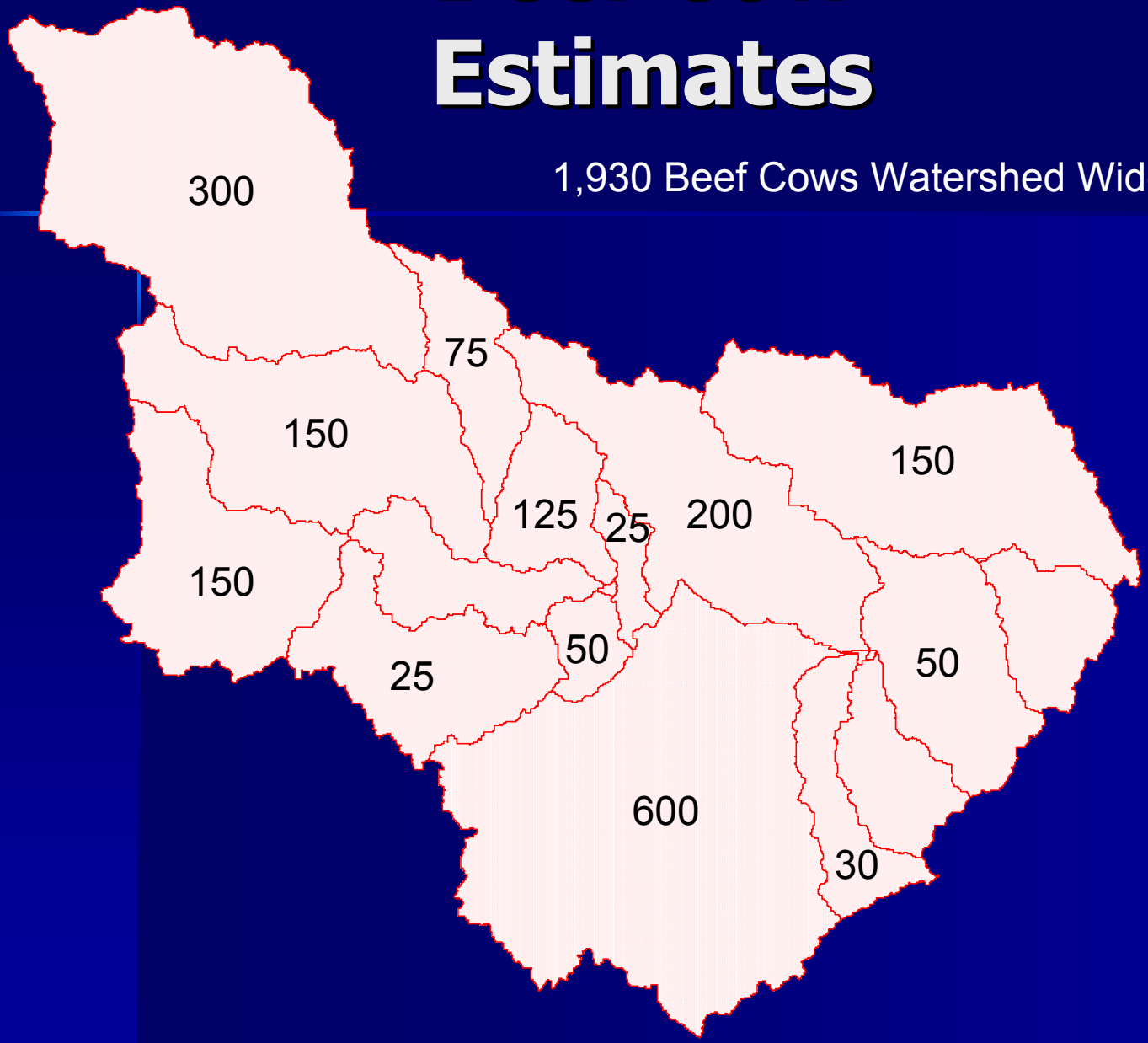
2,715 Dairy Cows Watershed Wide



Sub-basin	Milk Cows
1	250
2	0
3	0
4	0
5	0
6	540
7	415
8	0
9	0
10	335
11	0
12	0
13	0
14	575
15	0
16	0
17	0
18	600
19	0
20	0

Beef Cow Estimates

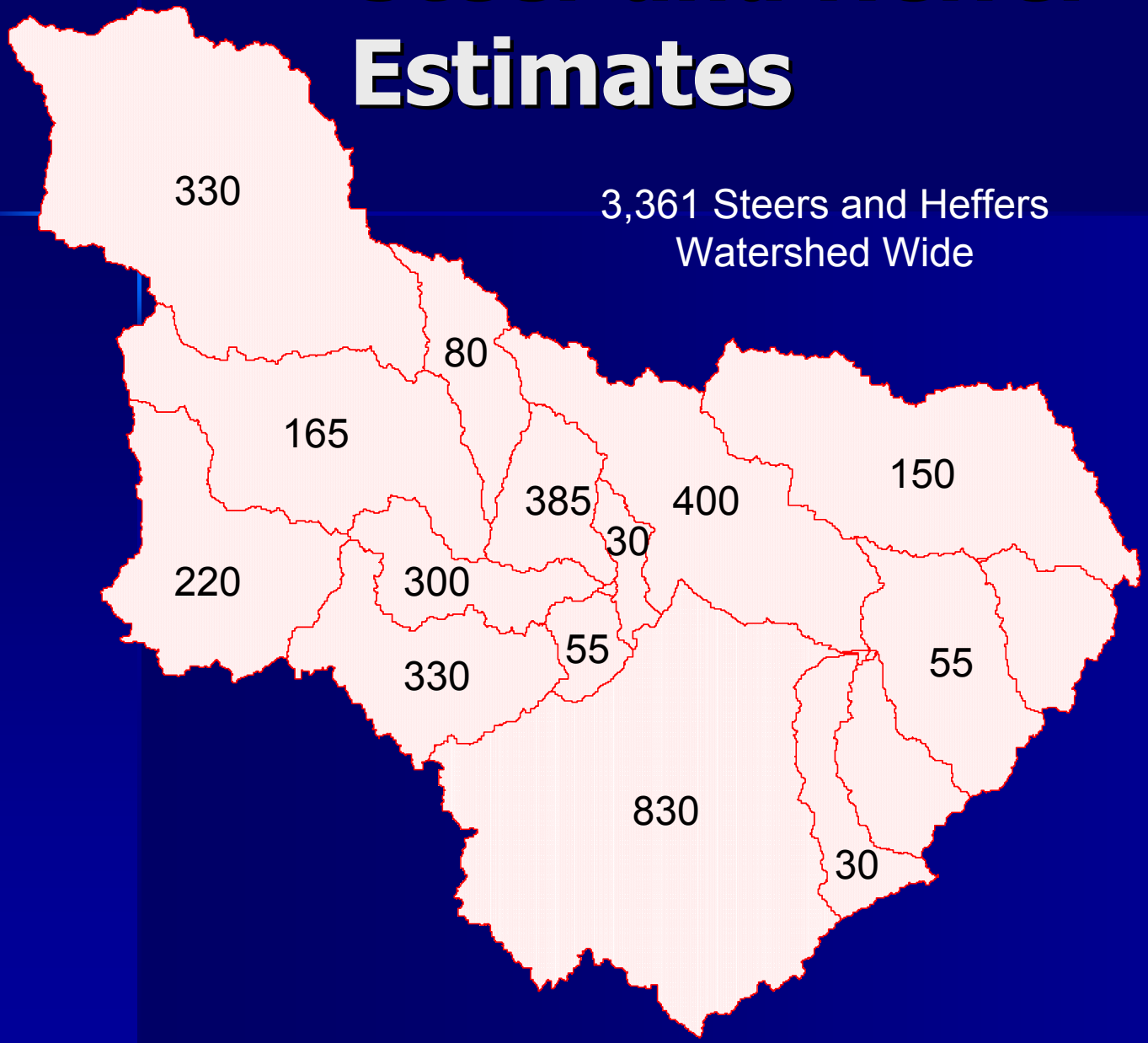
1,930 Beef Cows Watershed Wide



Sub-basin	Beef Cows
1	150
2	75
3	150
4	50
5	0
6	0
7	125
8	0
9	50
10	200
11	0
12	0
13	0
14	600
15	30
16	304
17	150
18	25
19	25
20	0

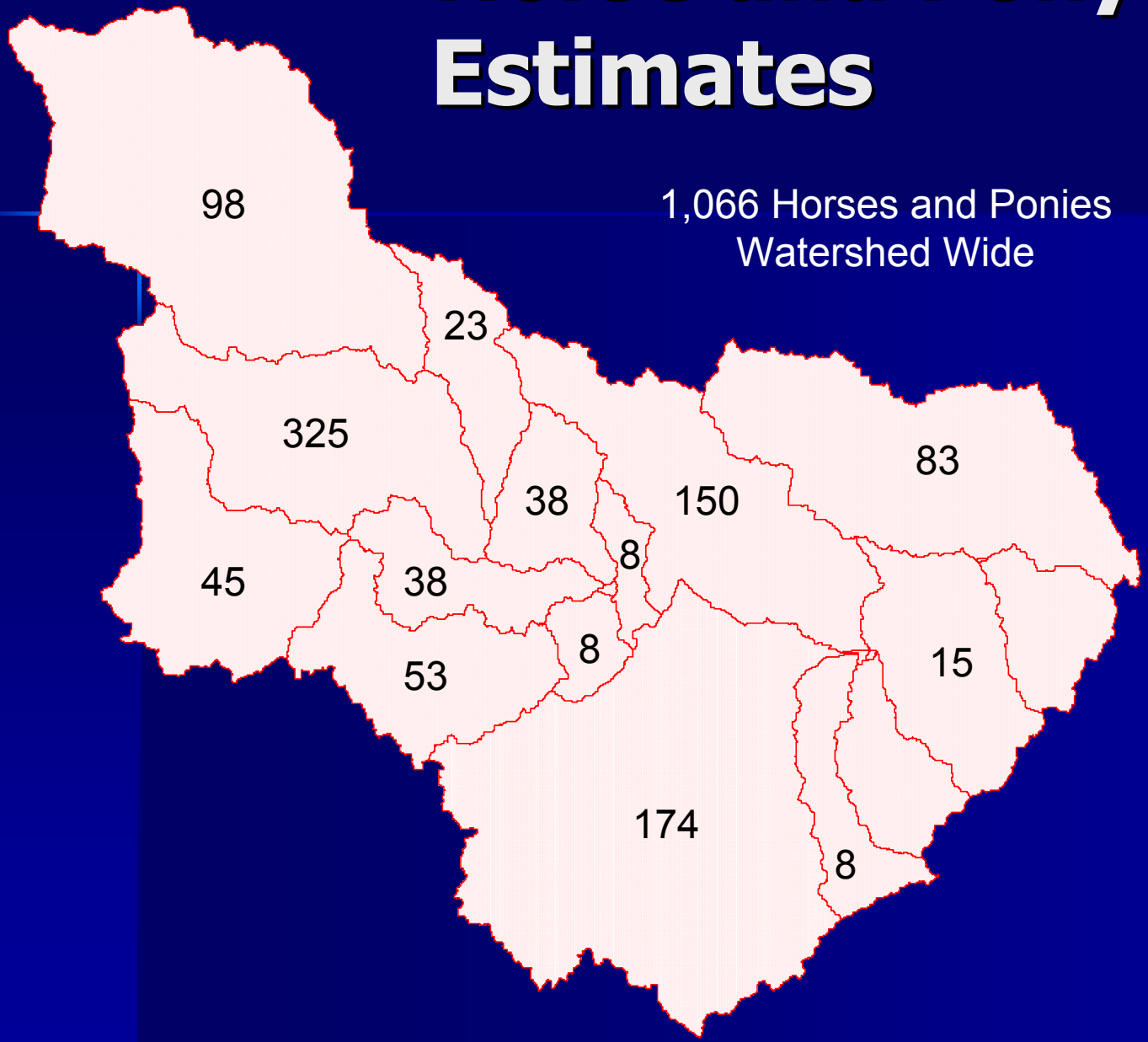
Steer and Heffer Estimates

3,361 Steers and Heffers
Watershed Wide



Sub-basin	Steers/ Heffers
1	150
2	80
3	165
4	55
5	0
6	300
7	385
8	0
9	55
10	400
11	0
12	0
13	0
14	830
15	30
16	330
17	220
18	330
19	30
20	0

Horse and Pony Estimates

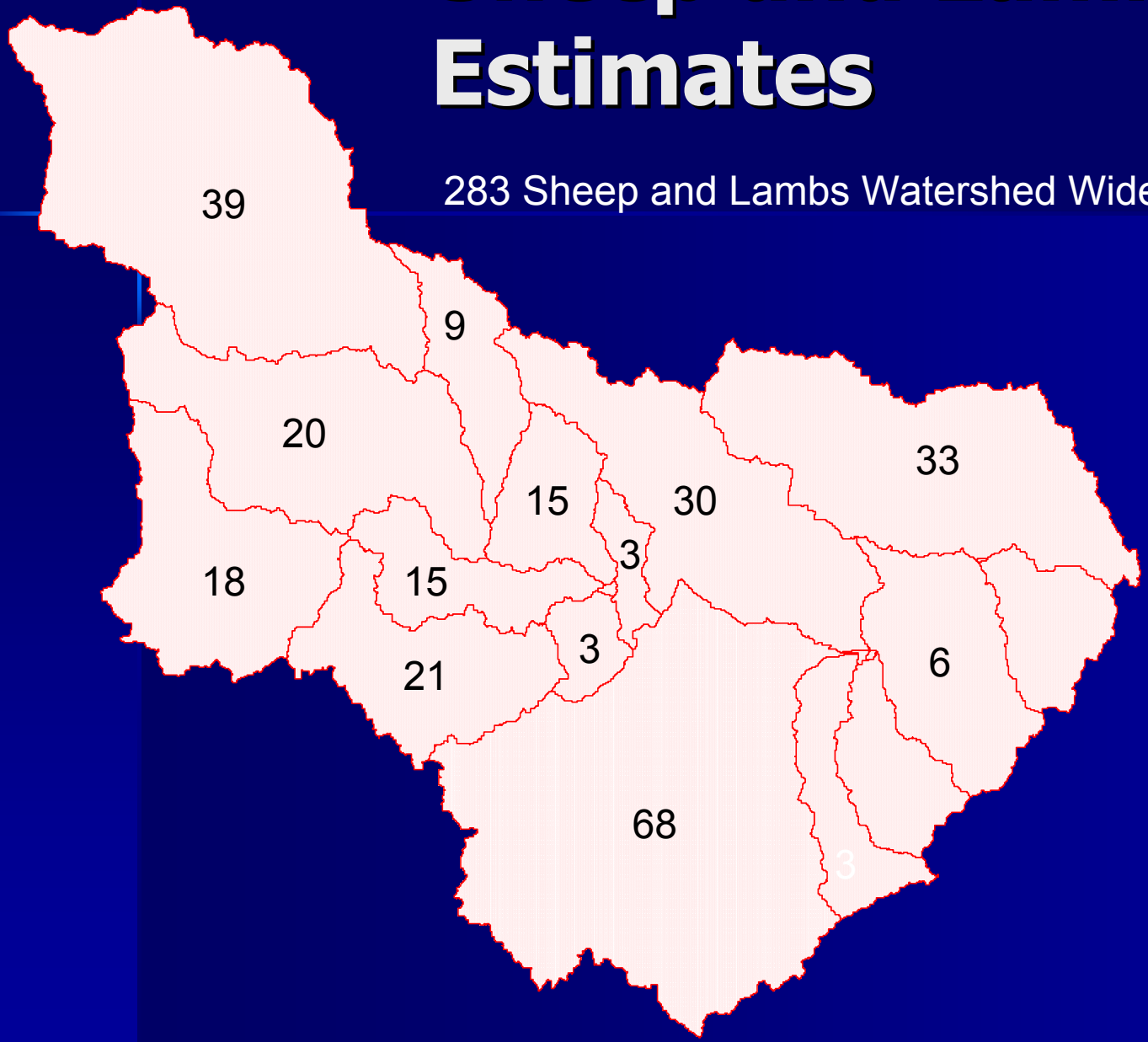


1,066 Horses and Ponies
Watershed Wide

Sub-basin	Horse and Pony
1	83
2	23
3	325
4	15
5	0
6	38
7	38
8	0
9	8
10	150
11	0
12	0
13	0
14	174
15	8
16	98
17	45
18	53
19	8
20	0

Sheep and Lamb Estimates

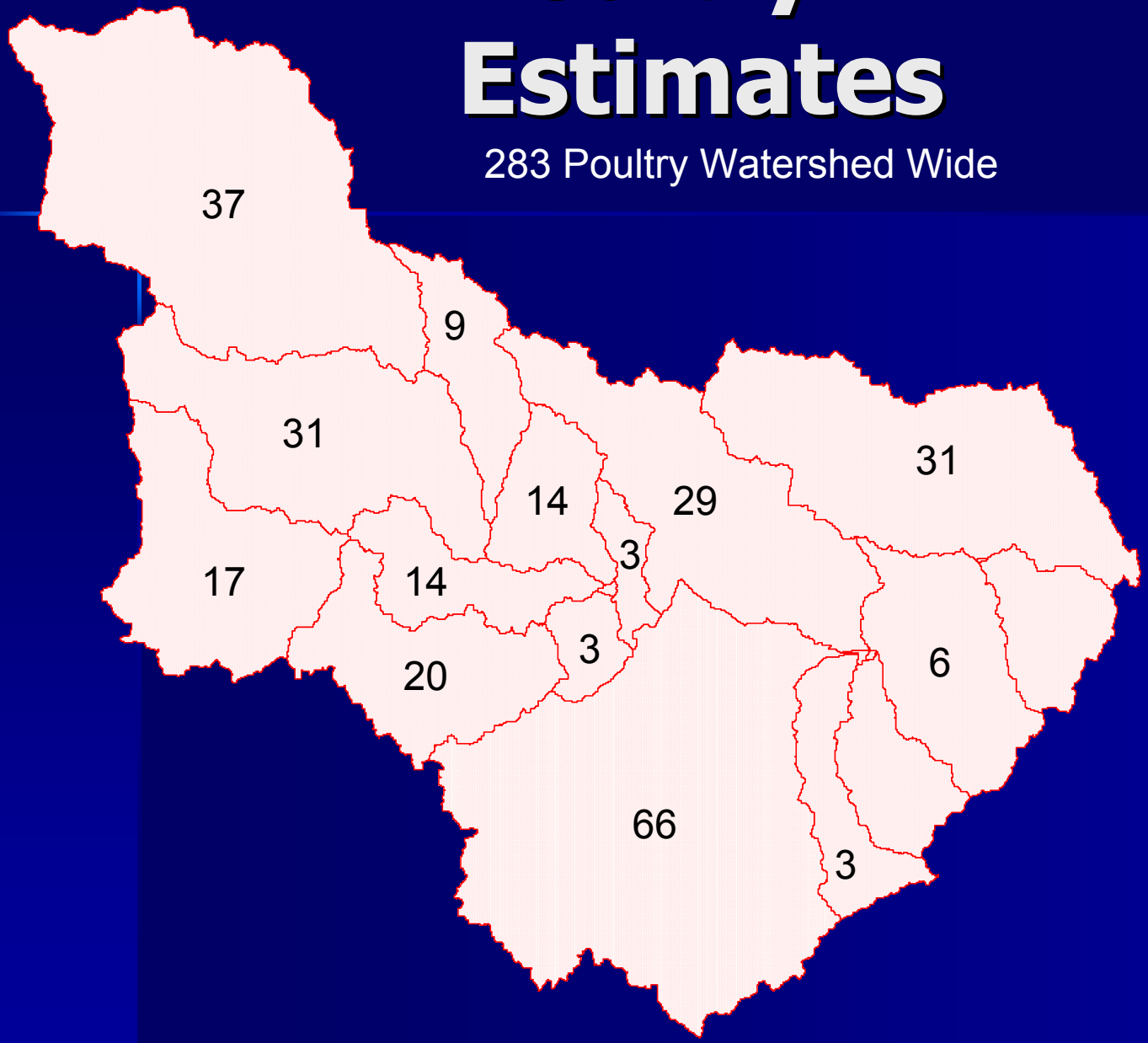
283 Sheep and Lambs Watershed Wide



Sub-basin	Sheep and Lamb
1	33
2	9
3	20
4	6
5	0
6	15
7	15
8	0
9	3
10	30
11	0
12	0
13	0
14	68
15	3
16	39
17	18
18	21
19	3
20	0

Poultry Estimates

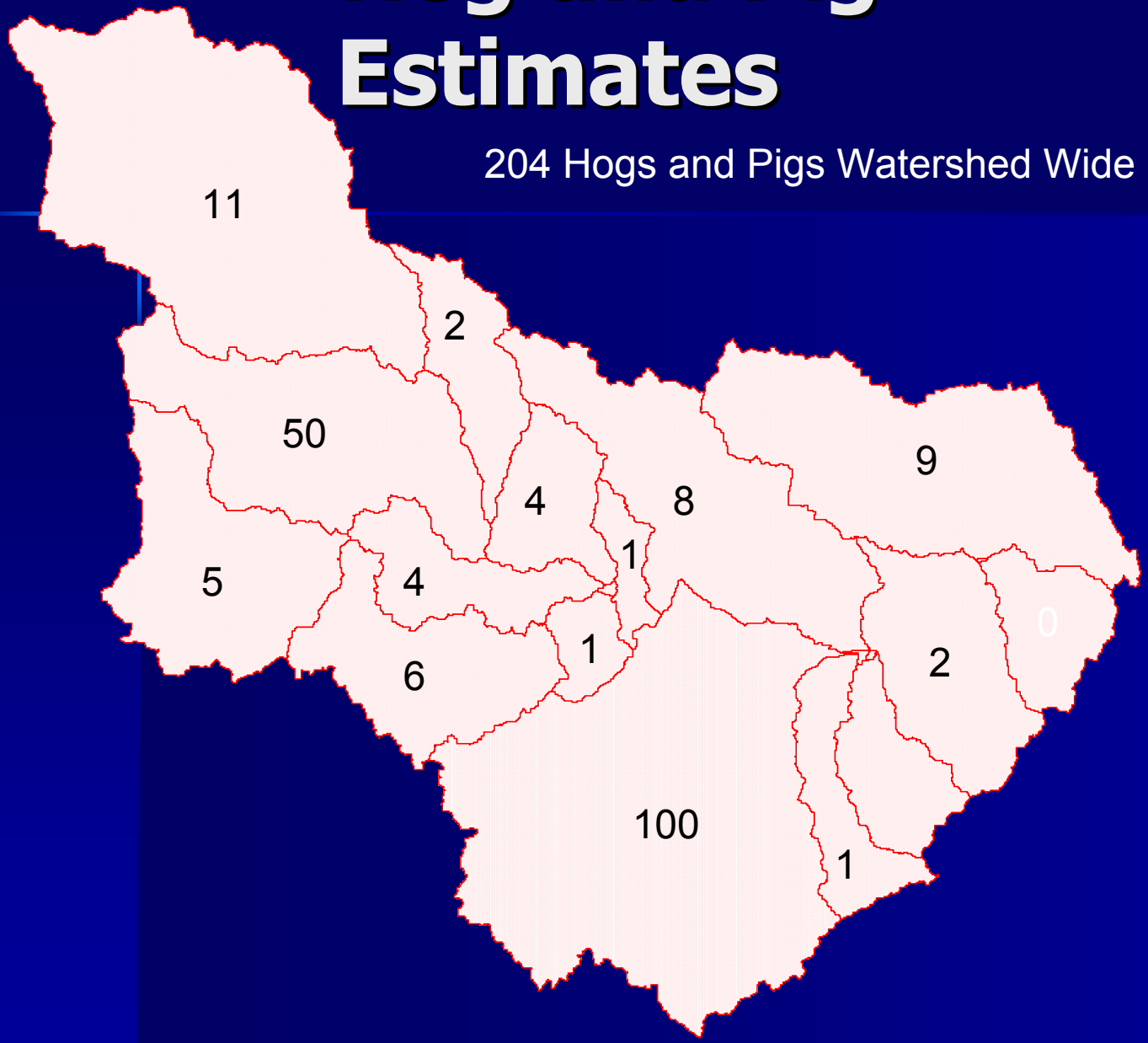
283 Poultry Watershed Wide



Sub-basin	Poultry
1	31
2	9
3	31
4	6
5	0
6	14
7	14
8	0
9	3
10	29
11	0
12	0
13	0
14	66
15	3
16	37
17	17
18	20
19	3
20	0

Hog and Pig Estimates

204 Hogs and Pigs Watershed Wide



Sub-basin	Hog and Pig
1	9
2	2
3	50
4	2
5	0
6	4
7	4
8	0
9	1
10	8
11	0
12	0
13	0
14	100
15	1
16	11
17	5
18	6
19	1
20	0

Goat Estimates

84 Goats Watershed Wide

Sub-basin	Goats
1	3
2	1
3	3
4	1
5	0
6	2
7	2
8	0
9	0
10	3
11	0
12	0
13	0
14	60
15	0
16	4
17	2
18	2
19	0
20	0

Dairy Cattle

Month	Hours Per Day in Confinement (Milk cows only)	Hours Per Day in Stream (All Cattle)	Hours Per Day in Pasture (Milk cows only)	Total Hours
January	9.6	0.05	14.4	24
February	9.6	0.05	14.4	24
March	9.6	0.5	13.9	24
April	7.2	0.6	16.2	24
May	7.2	0.77	16.03	24
June	7.2	1.0	15.8	24
July	7.2	1.0	15.8	24
August	7.2	1.0	15.8	24
September	7.2	0.77	16.03	24
October	7.2	0.6	16.2	24
November	9.6	0.5	13.9	24
December	9.6	0.05	14.4	24

Beef Cattle

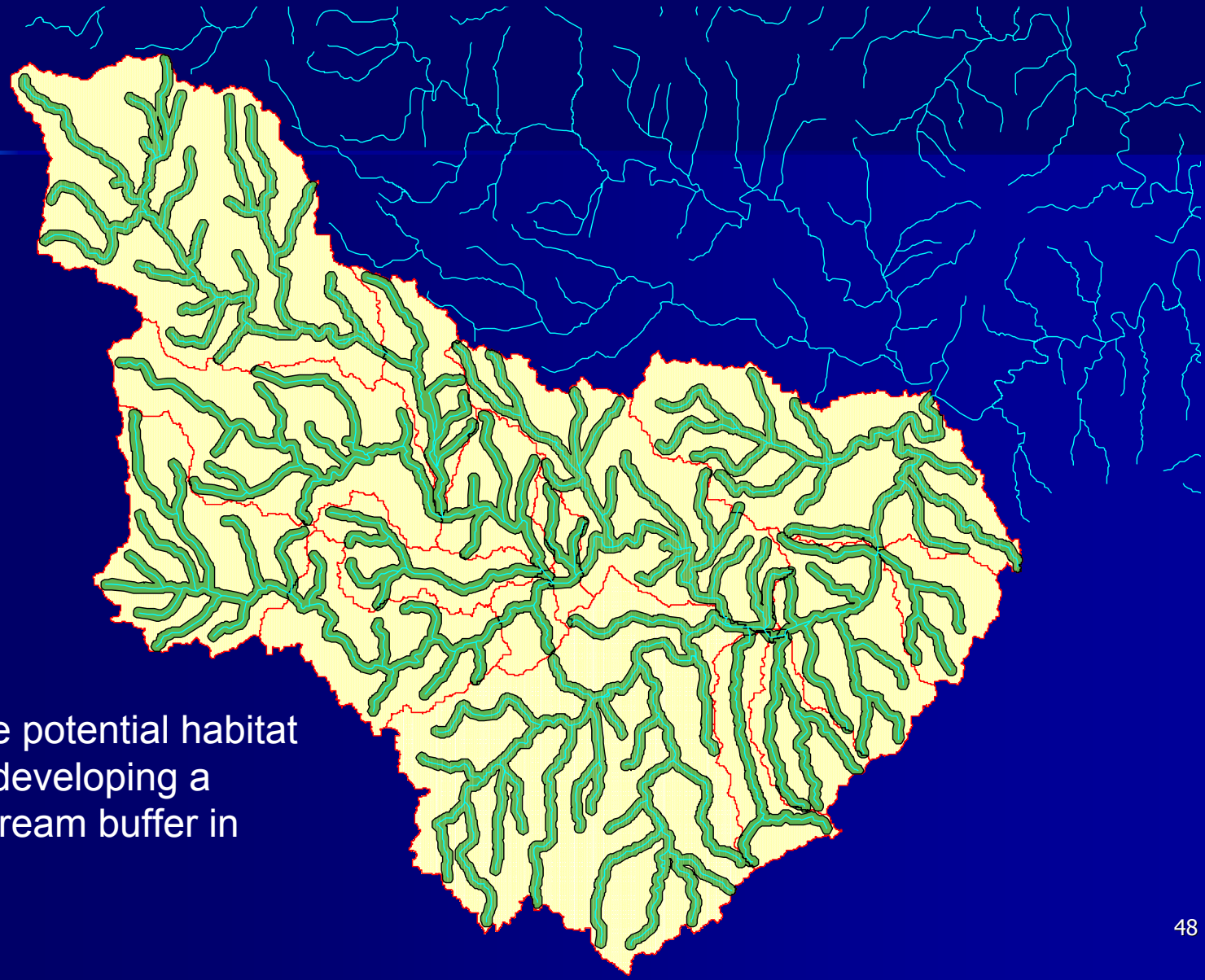
Month	Hours Per Day in Stream (All Cattle)	Hours Per Day in Pasture (All Cattle)	Total Hours
January	0.05	23.95	24
February	0.05	23.95	24
March	0.5	23.5	24
April	0.6	23.4	24
May	0.77	23.23	24
June	1.0	23.0	24
July	1.0	23.0	24
August	1.0	23.0	24
September	0.77	23.23	24
October	0.6	23.4	24
November	0.5	23.5	24
December	0.05	23.95	24

Wildlife and Habitat Estimates

- Based on Potential Habitats for Each Species:

Animal	Density	Habitat
Deer	0.084 / acre	Forest, pasture, cropland, pervious urban
Raccoon	0.070 / acre	Within 0 to 600 feet from continuous stream
Muskrat	2.750 / acre	Within 0 to 66 feet from continuous stream
Beaver	4.800 / acre	Continuous streams
Turkey	0.010 / acre	Forest
Goose	0.020 / acre	Within 0 to 66 feet from continuous stream
Duck	0.008 / acre	Within 0 to 66 feet from continuous stream

Raccoon Habitat



Calculate potential habitat area by developing a 600 ft. stream buffer in the GIS.

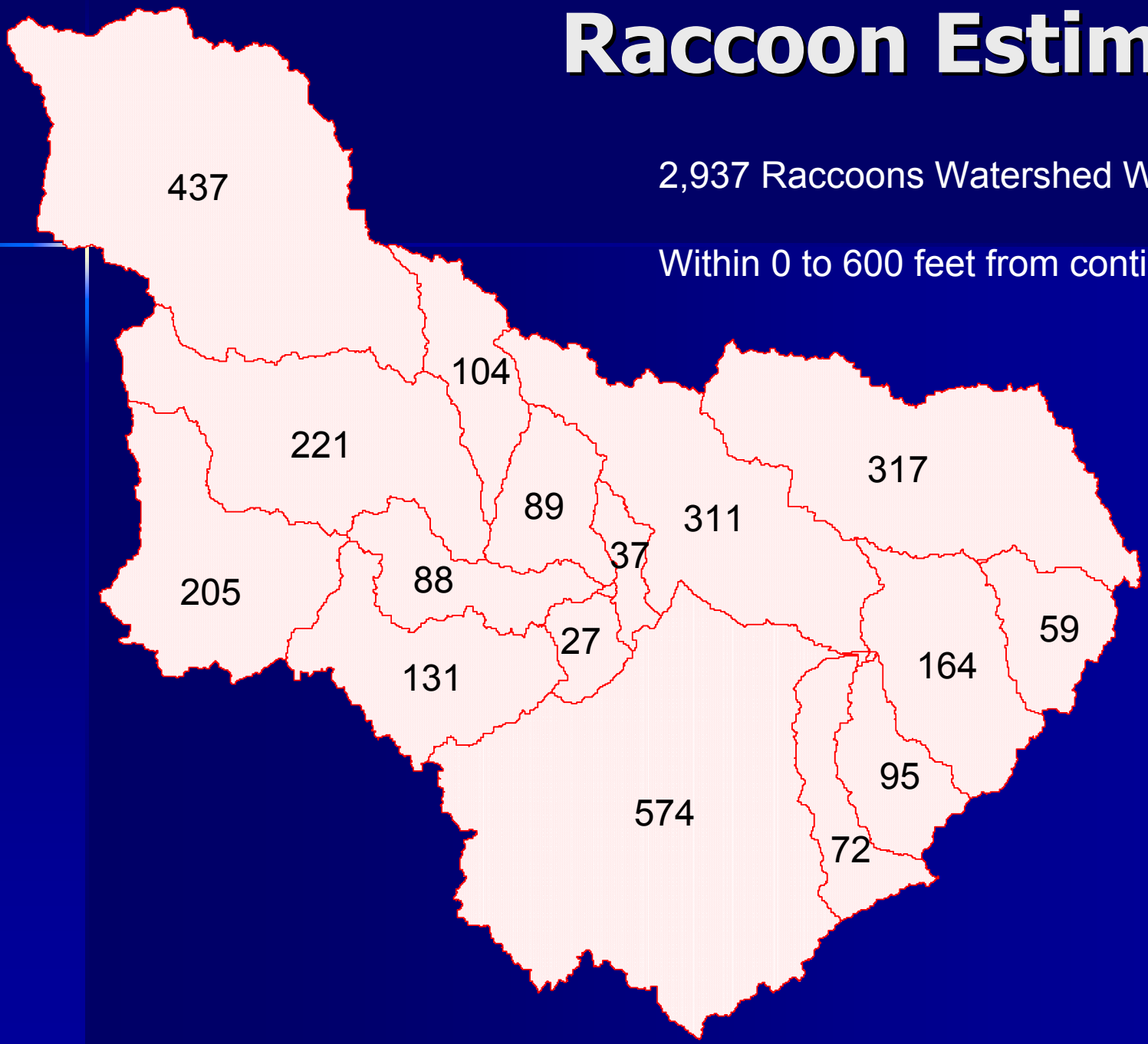
Wildlife Estimates

	Cedar Run Estimates
Raccoon	2,937
Beaver	420
Deer	1,936
Turkey	599
Muskrat	13,133
Goose (Migratory)	96
Duck (Migratory)	38
Waterfowl (Urban)	10,709

Raccoon Estimates

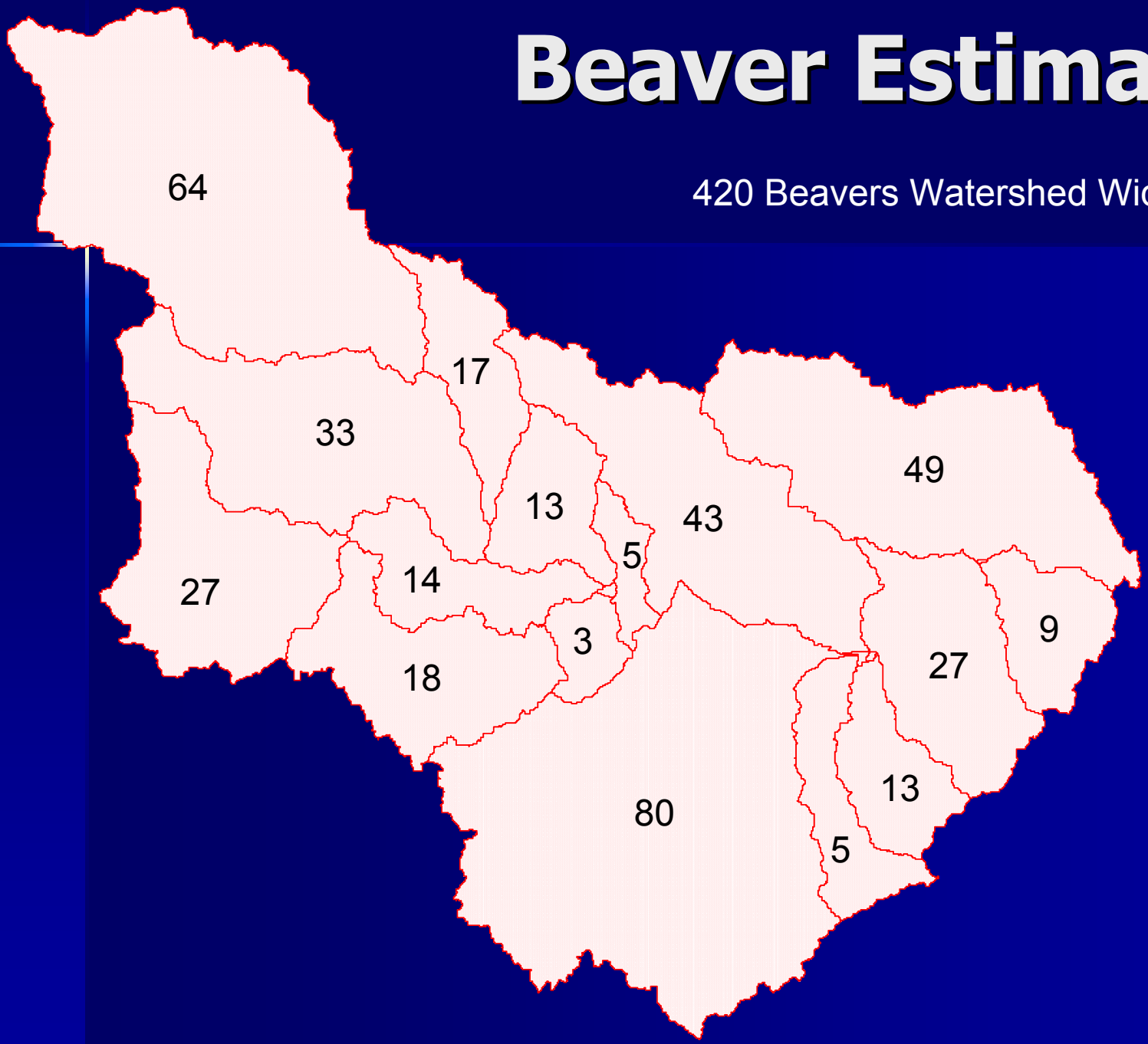
2,937 Raccoons Watershed Wide

Within 0 to 600 feet from continuous stream



Beaver Estimates

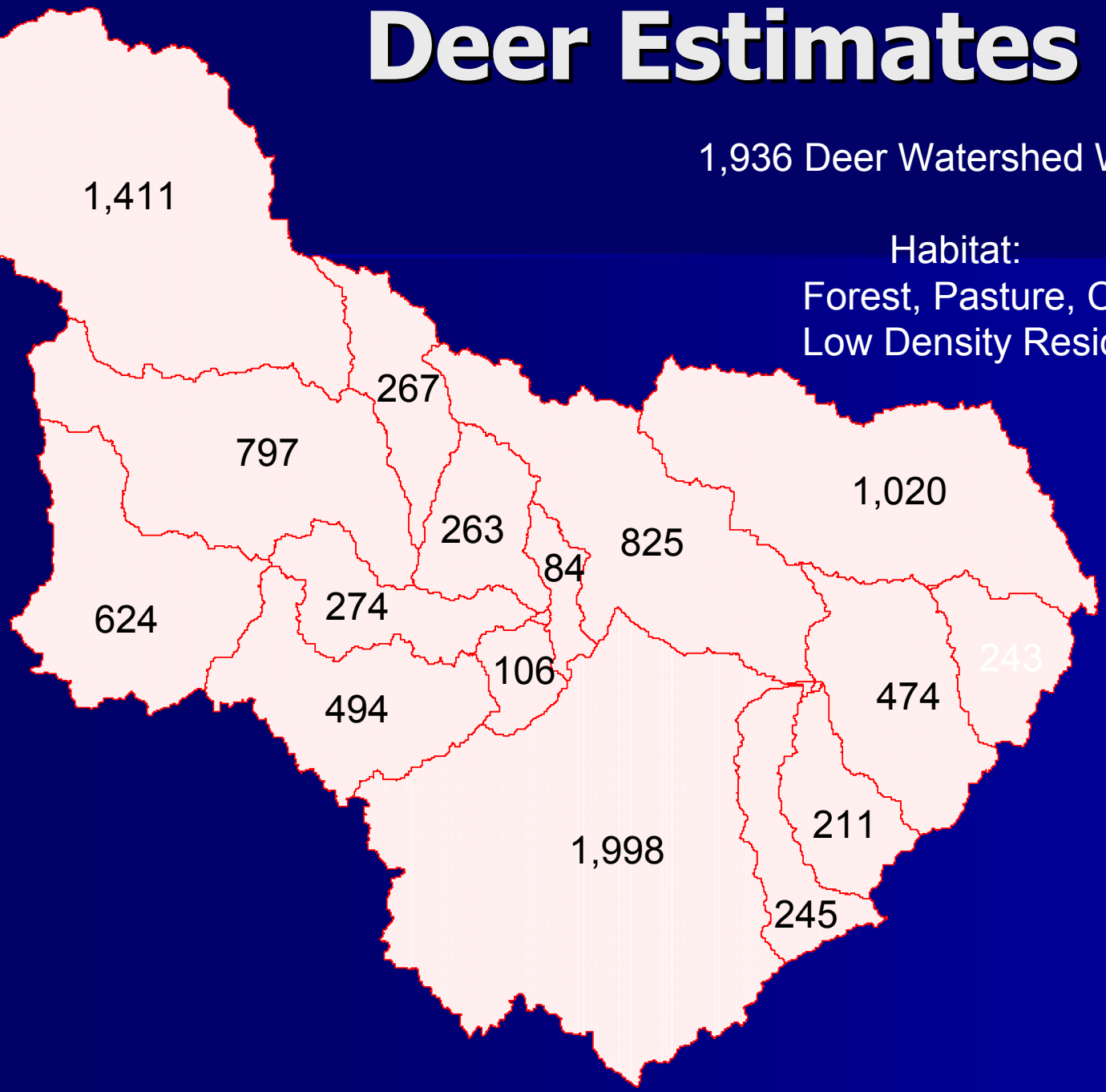
420 Beavers Watershed Wide



Deer Estimates

1,936 Deer Watershed Wide:

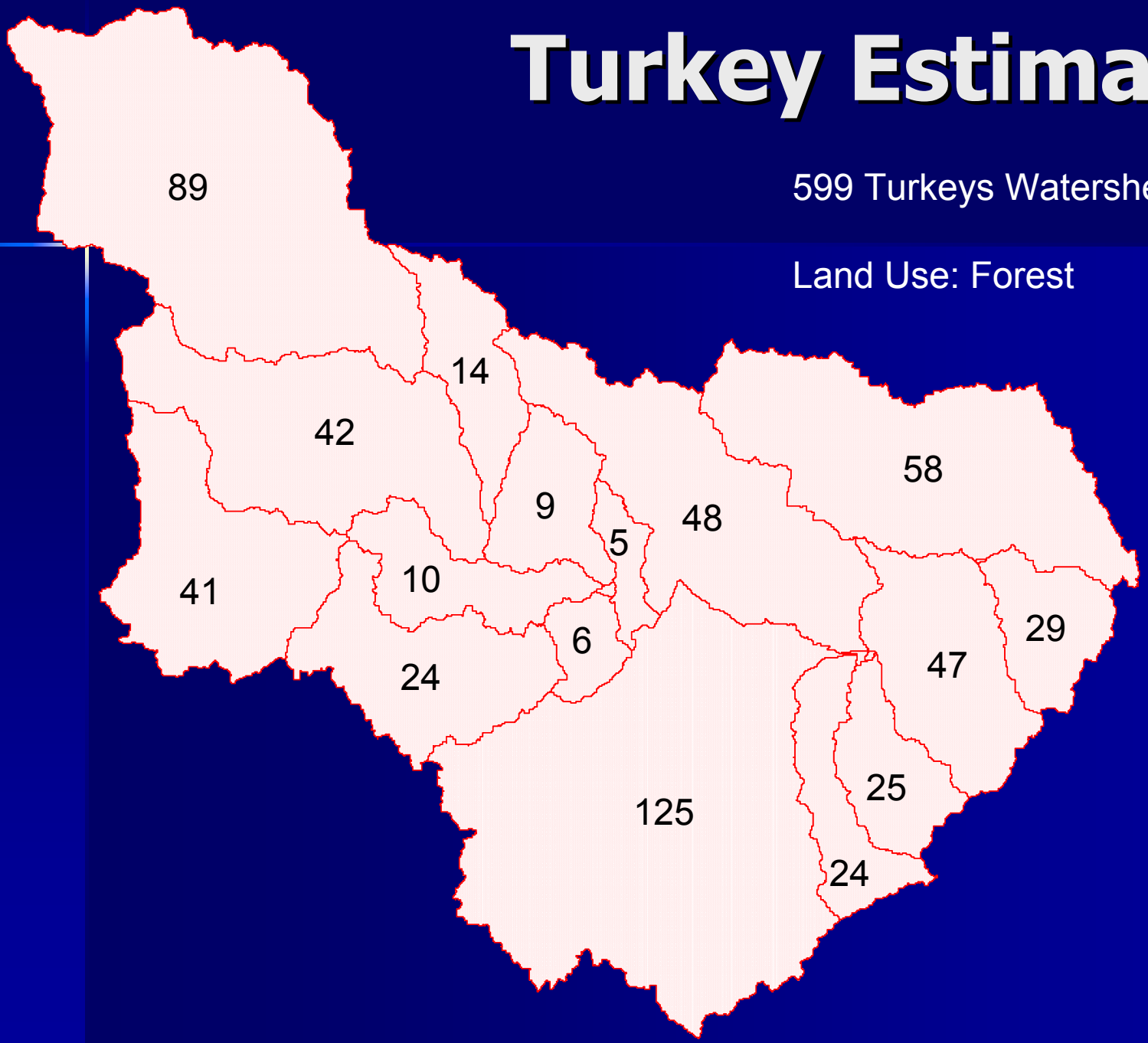
Habitat:
Forest, Pasture, Cropland,
Low Density Residential



Turkey Estimates

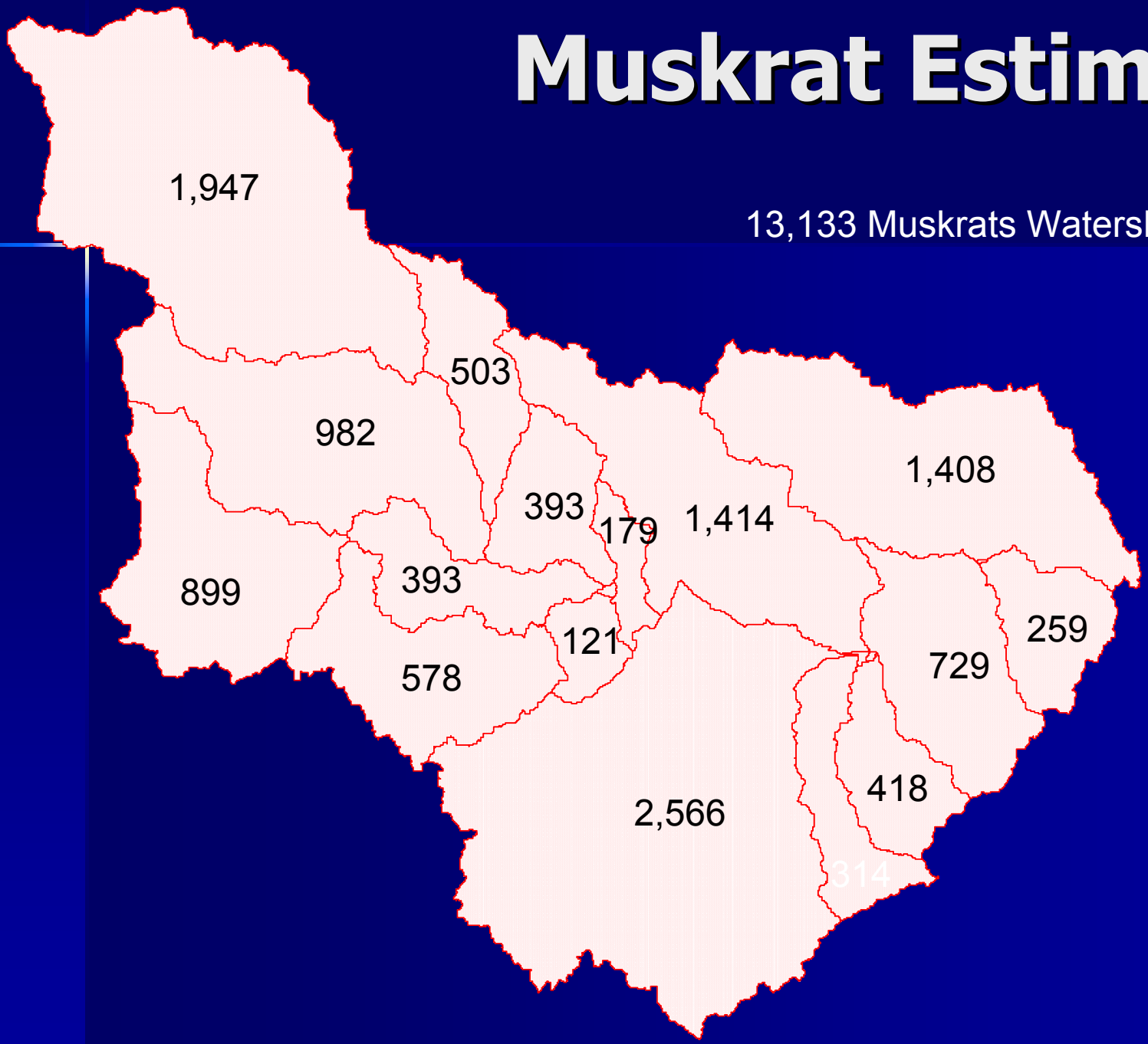
599 Turkeys Watershed Wide:

Land Use: Forest



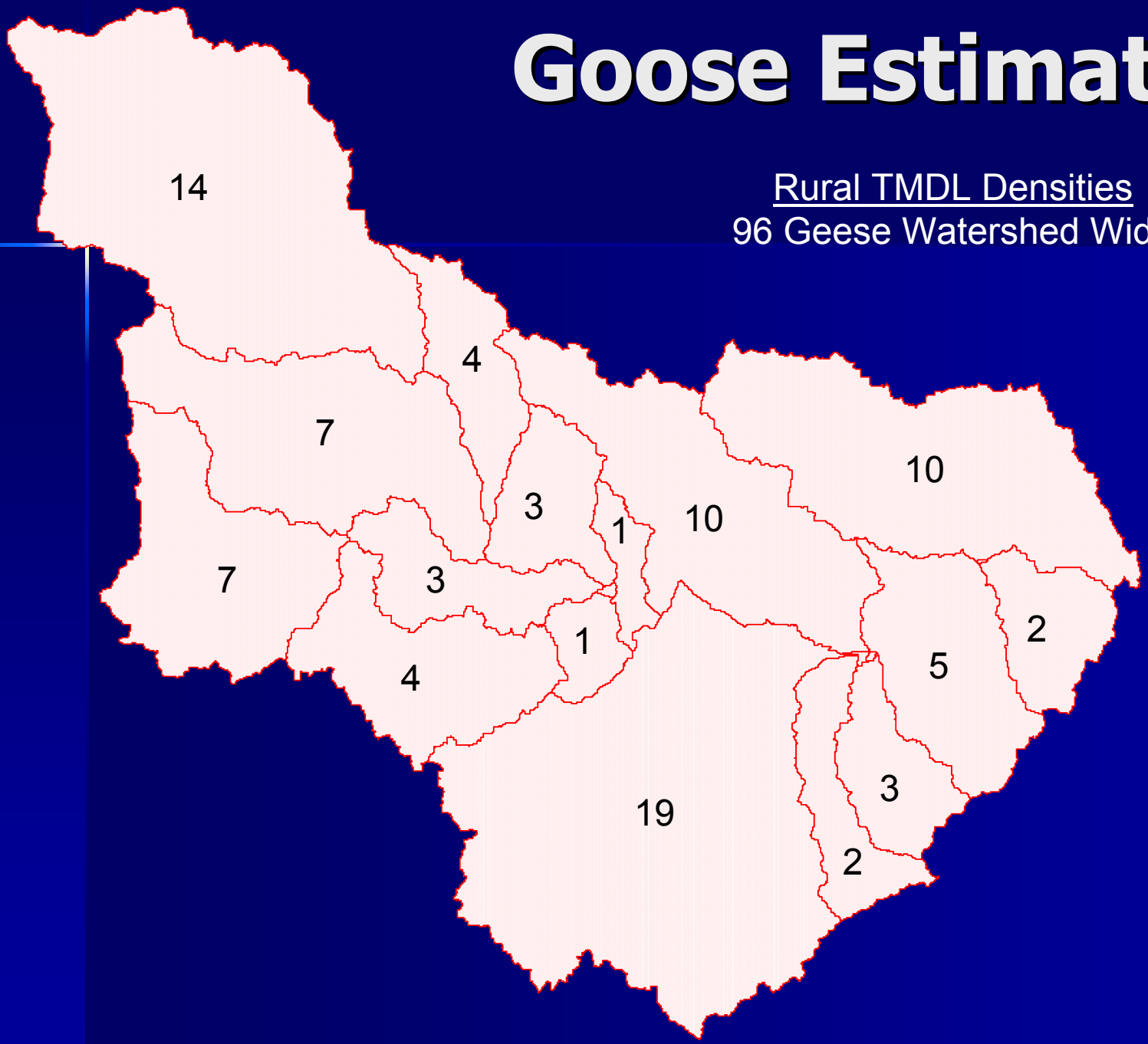
Muskrat Estimates

13,133 Muskrats Watershed Wide



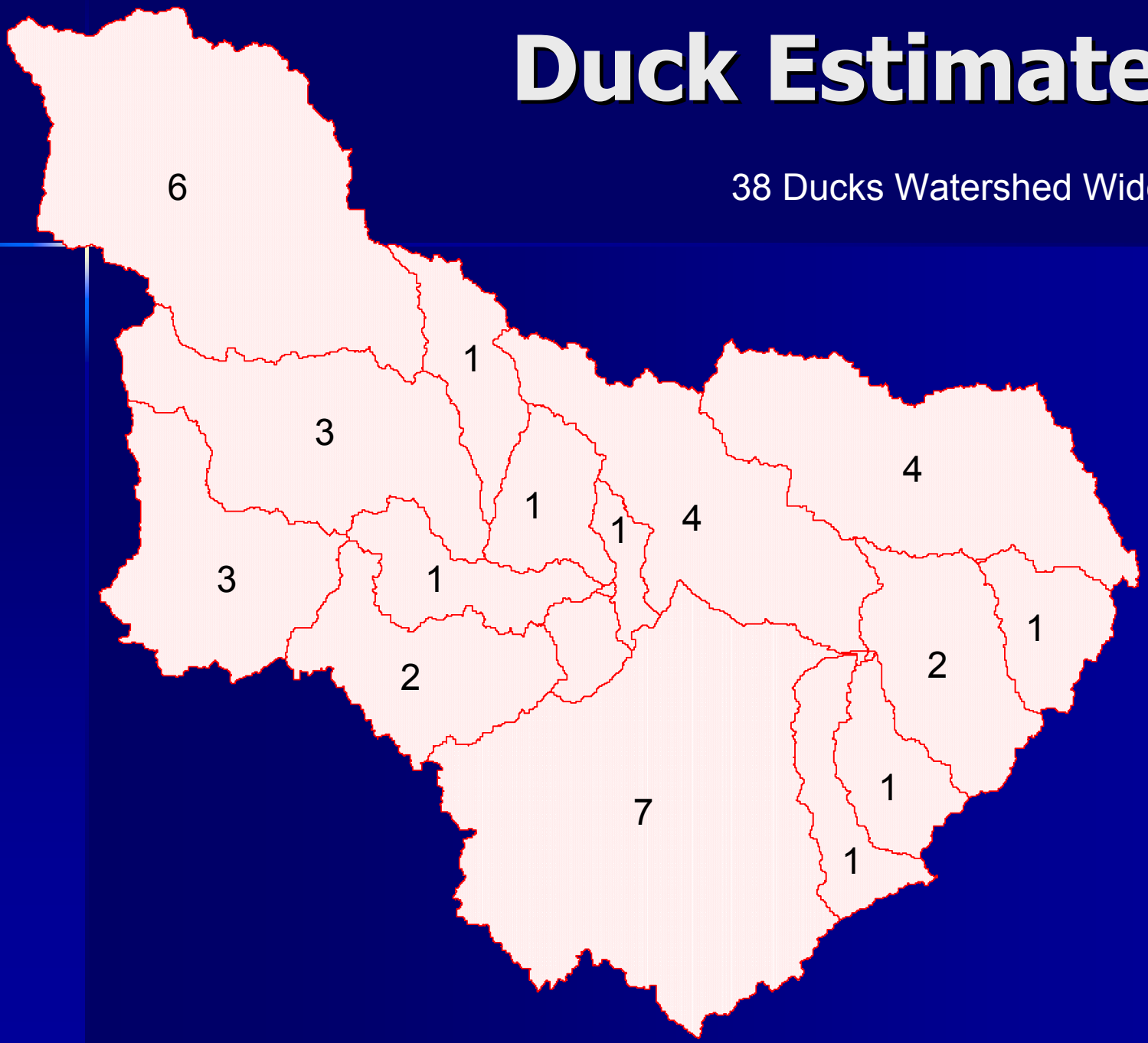
Goose Estimates

Rural TMDL Densities
96 Geese Watershed Wide



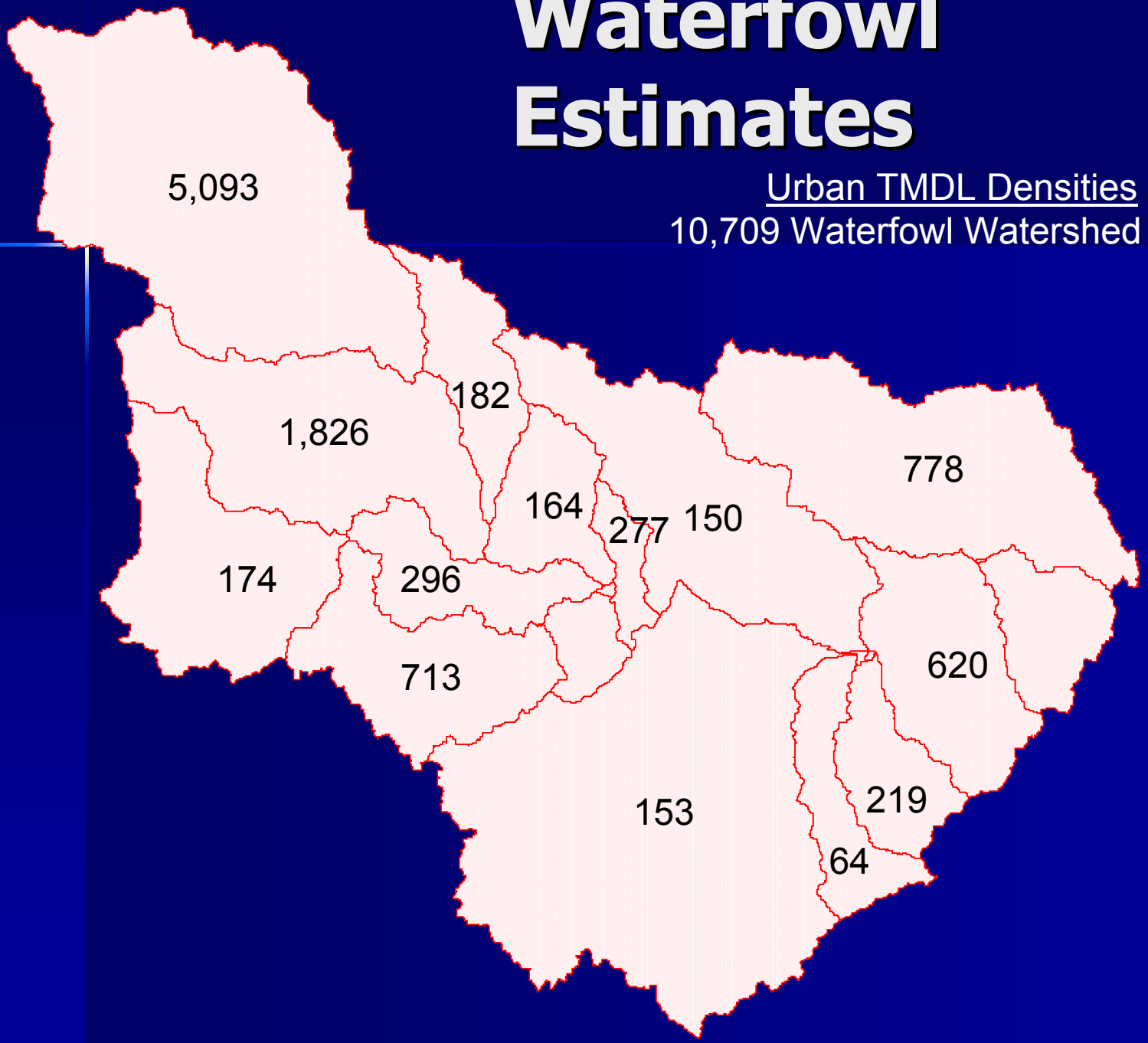
Duck Estimates

38 Ducks Watershed Wide

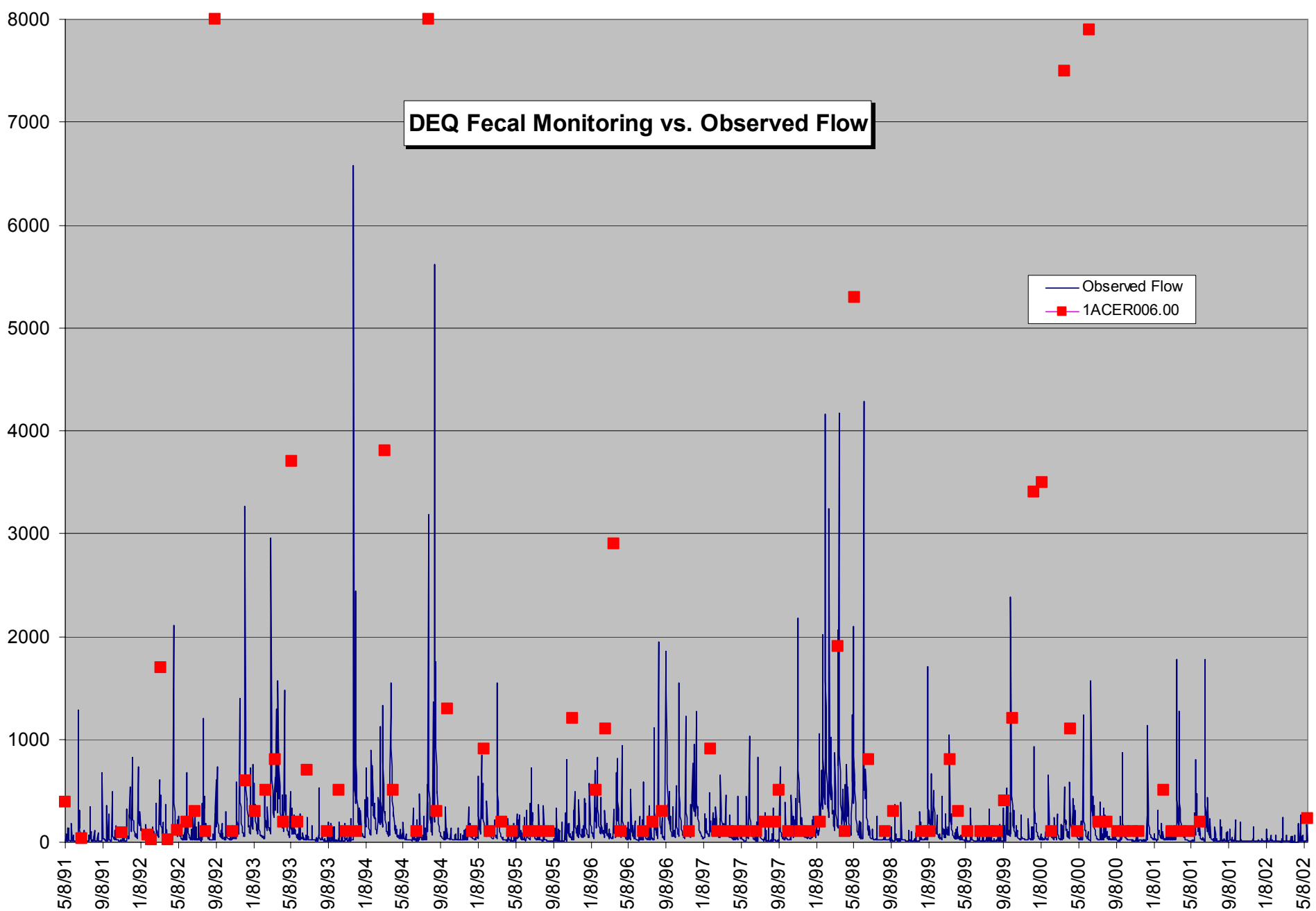


Waterfowl Estimates

Urban TMDL Densities
10,709 Waterfowl Watershed Wide



DEQ
Fecal Monitoring


DEQ Fecal Monitoring vs. Observed Flow
Observed Flow
1ACER006.00
8000
7000
6000
5000
4000
3000
2000
1000
0
5/8/91
9/8/91
1/8/92
5/8/92
9/8/92
1/8/93
5/8/93
9/8/93
1/8/94
5/8/94
9/8/94
1/8/95
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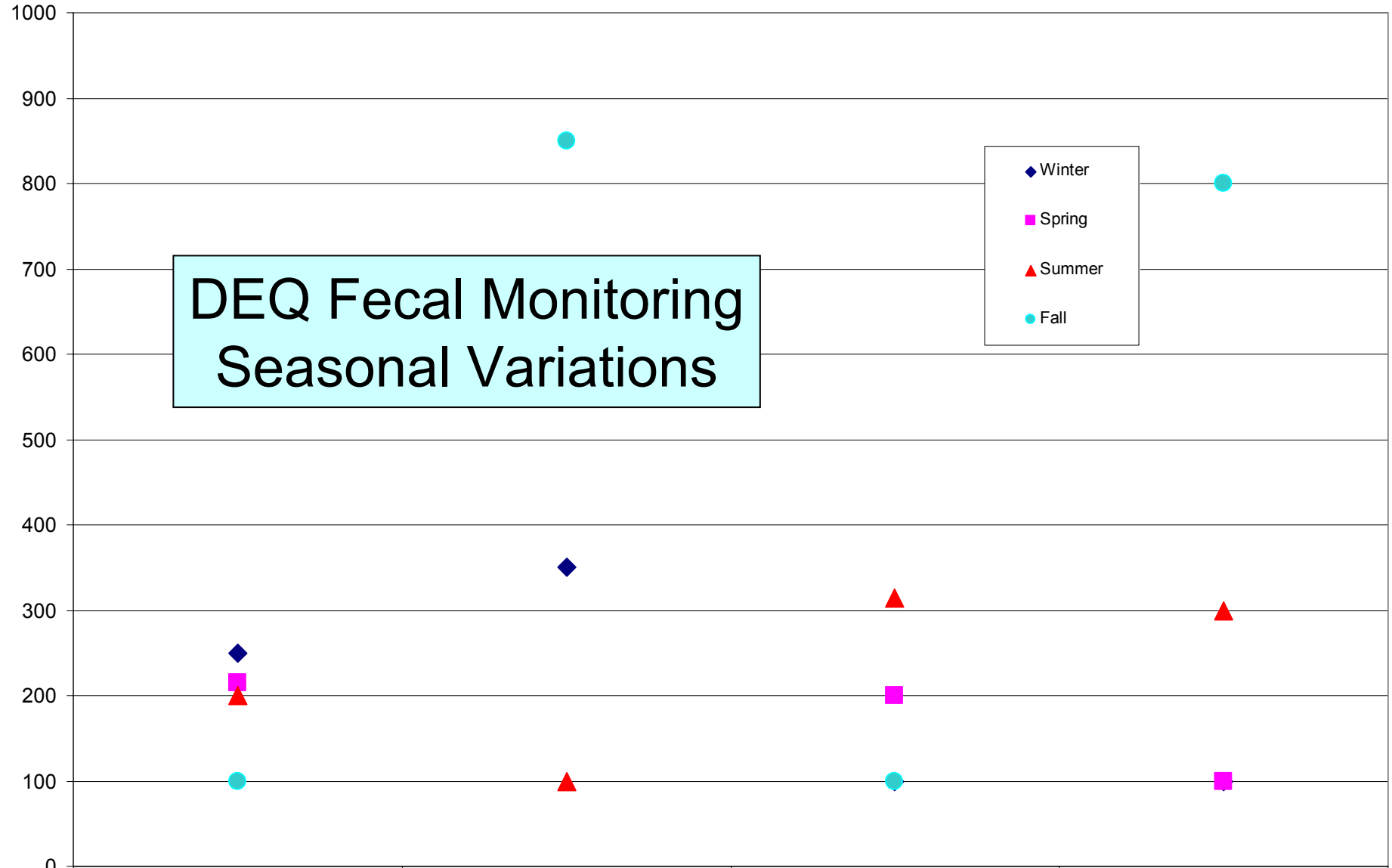
9/8/01
1/8/02
5/8/02



	Station 6.00	Station 9.52	Station 16.46	Station 25.25
Winter	22	2	11	8
Spring	28	2	12	11
Summer	26	5	9	8
Fall	18	2	11	11

Next Steps

- Reallocate Animal and Livestock Loads
- Develop Monthly Land and Stream Loads
- Calibrate WQ model component
- Develop Scenarios to meet WQ Criteria

Finally…..The End